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ORIGINAL ARTICLES.

I.—On a Boring for Coal at Presteign, Radnorshire.

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In March, 1912, a short paragraph in one of the London daily papers made the astonishing announcement that several beds of coal had been discovered on the Folly Farm, Presteign, and that boring would be started immediately. The astonishment was due to the fact that on the Geological Survey maps Presteign is represented as surrounded by Silurian and Old Red Sandstone formations, with no rocks of Carboniferous age nearer than the Clee Hills, 20 miles away in Shropshire. Unless, therefore, the Survey maps were wrong, and some unsuspected outlier of Coal-measures had been discovered, the name of the scene of operations was likely to prove prophetic.

While staying at Llandrindod in June following, it came to my knowledge that the proposed boring had not only been begun but had already reached a depth of several hundred feet. I therefore agreed to the suggestion of a resident of Llandrindod, interested in the scheme, that I should take the opportunity of visiting the borehole and reporting on its prospects. This I accordingly did on July 2, 1912, and found that it had been carried down through a series of mudstones, grits, and limestones, to a depth of 540 feet. Silurian fossils were found to be abundant in the rocks at the surface, and were present also in the cores brought up from various depths in the borehole. Yet in spite of my having at once submitted a report to this effect to one of the active promoters, urging him to abandon the scheme, the boring was not only continued to a total depth of 888½ feet, but was followed up by the cutting of a drift for some distance into the foot of an adjacent ridge of Wenlock Shales, Woolhope Limestone, and Upper Llandovery Sandstone.

It is scarcely necessary to say that, so far as the finding of coal is concerned, all these operations were foredoomed to failure, as the Silurian rocks contain no coal.[1]

The site of the boring[2] lies about 170 yards N. 17½° W. of the

[1] There is at least one simple precaution that can be taken by anyone before yielding to the temptation to invest in local coal-mining ventures in districts remote from the coalfields. Let an inquiry be addressed to the Geological Survey Office, Jermyn Street, London. A brief, civil, and possibly useful reply will be obtained at the cost of a penny stamp.

[2] The district is contained in the 1 in. Old Series Ordnance and Geological Map, Sheets 56 N.E. and S.E.; in the 1 in. New Series Sheet 180; and in the 6 in. Map of Radnorshire, Sheet 25 (Herefordshire 10) N.E.

Folly Farm, three-quarters of a mile south of Presteign. From the eastern suburb of the town a lane, turning southward out of the Tenbury road at the County Intermediate School, crosses the railway and rises towards the ridge of Nash Wood and Corton. At the foot of the ridge the lane bends to the south east, climbs the Folly Bank by a diagonal course close to the site of the boring, and soon reaches the summit at the Folly Farm (Fig. 1).

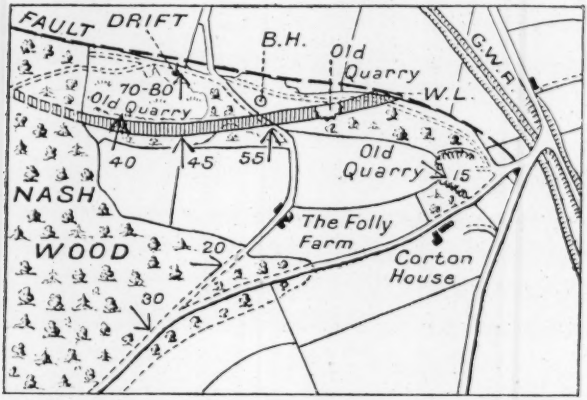


FIG. 1.—Sketch-map of the neighbourhood of Folly Farm, Presteign. Scale 6 inches to a mile. B.H., bore-hole; W.L., Woolhope Limestone.

The mouth of the drift can be seen at the foot of the ridge, about 60 yards west of the bend in the lane, and 140 yards west-by-north of the borehole. The excavation was driven in a direction bearing about S. 16° W., i.e. at right angles to the trend of the ridge, and descends at a slight angle from the horizontal. It thus cuts the beds in descending order at about right angles. Judging by the amount of material brought out, it must have penetrated a considerable distance into the hill-side before it was abandoned through lack of further funds.

Murchison[1] in 1839 sketched the outlines of the geology of Presteign in the classic pages of *The Silurian System*. He clearly perceived the anticlinal structure of the Nash and Corton ridge, and its connexion with the disturbed region of Old Radnor. He saw that the visible core of the ridge is composed of grits and conglomerates, which he correlated with the upper beds of the Caradoc Sandstone of Shropshire, and that these grits rise on each side from beneath a calcareous zone, which he regarded as the equivalent of the Wenlock Limestone. He noted also that the grits contain the characteristic fossils of the upper beds of his Caradoc Sandstone, e.g. *Pentamerus oblongus* and *P. lævis*, and that the overlying limestone, which, on the northern side of the ridge,[2] occurs in the form

[1] *Silurian System*, pp. 313, 314, 321, 322.

[2] This outcrop has been variously referred to as the limestone at the Folly (Murchison), at Folly Bank (J. E. Davis), at Corton (Murchison and W. S. Symonds), and at the Sandbanks (J. E. Davis). It will facilitate description

of nodules and two thin bands subordinate to shale, yielded (to quote the original nomenclature) *Asaphus caudatus*, *Calymene variolaris*, *C. macrophthalma*, and *Isotelus*.

For the most complete geological description of the district the inquirer must turn to a paper read before the Geological Society of London in May, 1850, by J. E. Davis,[1] apparently only a month before the first issue of the Geological Survey map. The purpose of the author was to show that the limestone of Nash and Presteign is of Wenlock age, as had been stated by Murchison in 1839, and not of Woolhope age, as Sedgwick had surmised as a result of a visit in 1846. Incidentally we gather that on the northern side of the Corton ridge the limestone formerly quarried at "the old and now abandoned excavations . . . at the 'Sandbanks'" is about 8 feet thick, is highly crystalline, is separated from the Caradoc Sandstone by a few feet of shale, and is overlain by a greater thickness of Wenlock Shale. He pointed out that the sandstone contains abundant specimens of *Pentamerus oblongus*, Sow., *Atrypa hemispherica*, Sow., and various species of *Orthis*. From the limestone of the Sandbanks he recorded only *Orthis pecten?*, Dalm., *Lingula quadrata?*, Eichw., and *Orbicula Forbesi*, Dav. He gave a long list of fossils from the Wenlock Shales of the Sandbanks, and remarked that fragments of *Bumastus barriensis* (Murch.) [=*Illænus barriensis*] occur in great abundance.

The first edition of the Geological Survey map (56 N.E.), undated, but published probably in 1850, showed the Corton ridge as an anticline of "Caradoc Sandstone", with a band of "Silurian limestone" dipping off its northern foot and succeeded by the Wenlock Shale. On a later edition (dated June, 1850, though probably this date refers to the publication of the first edition) the nomenclature is brought up to date, the term "Caradoc Sandstone" being replaced by "Upper Llandovery Rock", while the limestone is definitely referred to as "Woolhope Limestone".

In 1854 Murchison,[2] in his *Siluria*, an abridgment of his earlier work, devoted a woodcut to a longitudinal section of the ground lying between Corton and Presteign. He represented the Caradoc [Upper Llandovery] Sandstone or Corton Grit as dipping steeply northward under a group of shales with subordinate courses of limestone, which he named "Lower Wenlock Shale and Woolhope or Lower Wenlock Limestone". He thus tacitly relegated the limestone to an horizon between the Caradoc and the Wenlock Shales, and definitely correlated it with that of Woolhope. He also noted that the Corton Grit is laden with the casts of *Pentamerus oblongus*. In later editions of the same work[3] he accepted the separation of the

if we call it the Presteign Limestone, or the Presteign outcrop of the Woolhope Limestone. The other outcrop, on the southern side of the ridge, is known as the Nash or Nash Scar Limestone.

[1] "On the Age and Position of the Limestone of Nash, near Presteign, South Wales": Quart. Journ. Geol. Soc., vol. vi, pp. 432–9, with a section, 1850.

[2] *Siluria*, 8vo, 1st ed., 1854, pp. 89, 90, 102, 103.

[3] e.g. in 3rd ed., 1859, pp. 101, 117, 118.

Pentamerus Beds from the Caradoc Sandstone, and adopted the term "Upper Llandovery Rock" for the Corton Grit, in which he noted the occurrence of *Pentamerus oblongus*, *Atrypa hemispherica*, *Petraia elongata*, and *P. bina*.

The Rev. W. S. Symonds[1] appears to have been one of the first observers to perceive that the Presteign Limestone is of Woolhope and not Wenlock age. He based this conclusion on the facts that here, as elsewhere, the limestone in question follows immediately upon the "Caradoc" [i.e. the Upper Llandovery], and contains *Illænus barriensis* and *Homalonotus knighti* in far greater abundance than does the Wenlock formation. The same author, in a later and better-known work,[2] remarked that as early as 1850 he had correlated the Presteign Limestone with that of Woolhope by its position with respect to the Upper Llandovery beds and from its containing *Illænus barriensis* in abundance.

Turning now to the current edition of the Geological Survey maps (Sheets 56 N.E. and S.E.), we see that Presteign stands on a great line of faulting, which, ranging in a south-south-westward direction from beyond Church Stretton, runs through Bucknell in the Teme Valley, passes Presteign, and, five miles farther to the south-west, near Old Radnor, brings to the surface the ancient igneous rocks of Stanner, Worsell, and Hanter.

On the western or downthrow side of this fault a broad strip of Old Red Sandstone extends from Bucknell to within a mile of Presteign. Though now cut through by the valley of the Lugg, this strip was once continuous with a second tract of the same formation, which underlies Upper Radnor Wood and Knill Wood, south-west of the town.

On the eastern or upthrow side of the fault, grey calcareous sandy mudstones of the Ludlow formation extend from Brampton Bryan Park to within a mile of Presteign, where they give place to the Wenlock Shales, though these are concealed for a space by the superficial gravels and alluvia of the Lugg. Southward, beyond these valley deposits, the lowest beds of the Wenlock Shales soon emerge along the northern slopes of the anticlinal ridge of Nash Wood and Corton. For a distance of half a mile along the northern foot of this ridge, and dipping northward from it at an angle of 41°, a lenticular outcrop of the Woolhope Limestone comes to the surface at the spot named Folly[3] on the Map (56 N.E.), thinning out to a point, both eastward and westward, between the Wenlock Shales above and the Upper Llandovery Rock below. Immediately south of the limestone outcrop rises the Corton ridge itself, which consists of Upper Llandovery Rock, locally known as the Corton Grit. Several dip-arrows on the map show that the ridge is an anticline. It

[1] *Old Stones*, 8vo, 1855, pp. 59, 60.

[2] *Records of the Rocks*, 8vo, 1872, pp. 139, 140, 160.

[3] On the Ordnance Map, which was published October 1, 1833, this name is placed at the northern foot of the ridge, where the lane from the town begins its diagonal ascent. It may have referred to a cottage shown above the old limestone quarries. The cottage is still remembered by old inhabitants, but the name now applies to the farm on the crest of the ridge.

emerges from the flats of the Lugg near Corton, and trends south-westward under Folly Farm and through Nash Wood toward Nash Scar, where a second outcrop of Woolhope Limestone dips off its southern flank and has till quite recently been quarried and burnt for lime.

From these particulars, which for over half a century have been accessible in the works quoted, it will be seen that a more hopeless district in which to sink for coal could hardly have been found if deliberately sought for. This is not the place to criticize the pseudo-geological statements put forward in support of the scheme; it is sufficient to remark that one of the leading promoters regarded the line of old excavations on the course of the Woolhope Limestone, together with the presence of small pieces of unburnt coal in the soil, as positive proof that the outcrop of a coal-seam had been at some time worked there by opencast.

My hasty visit in July, 1912, and a brief examination made in September, 1915, confirm in all their main features the views expressed by previous observers; but the record of the boring shows that the structure of the ground is not so simple as appears at first sight.

The Corton Grit, consisting of hard and relatively durable conglomerates, grits, and sandstones, forms the dominant feature of the landscape. The rock has been extensively quarried at the eastern end of the ridge, where a large excavation, 100 yards north of Corton House, shows 30 or 40 feet of massive grits and coarse grey sandstones. Quartz and quartzite pebbles are present, and in some cases are claret-coloured. The dip (E.S.E. at 15°) shows clearly the pitch of the anticline. A rotten fossiliferous band about half-way up the western face yielded '*Petraia*' *elongata* (Phill.). In the lane that ascends the Folly Bank, past the boring, to the Folly Farm, excellent exposures show a northward dip of 55°; others, a few yards farther south, and within 70 yards of the site selected for the boring, yielded specimens of '*Petraia*' *elongata* and casts of *Pentamerus oblongus*, J. de C. Sow. On the southern side of the ridge the same lane again shows the grits with *Pentamerus*, dipping first eastward, and then south-eastward, at 20° to 30°.

The Woolhope Limestone has been at some time extensively quarried and burnt for lime along the northern foot of the ridge. The works had evidently been abandoned before the appearance of J. E. Davis's paper in 1850; but the quarries are clearly marked on the Ordnance Map of 1833. As traces of several small earthen kilns of horse-shoe shape can still be detected among the excavations, the presence of pieces of coal in the soil is not to be wondered at. Though little of the limestone is now visible, the old openworks west of the lane show that the bed cannot exceed, if it attains, 12 feet in thickness, that it follows close upon the Corton Grit, and is succeeded by mudstones referable, apparently, to the Wenlock Shales. The high southern side of the excavation affords a fine view of the grit, with large bare bedding-planes, dipping northward at 40° to 45°, and studded with quartz-pebbles of the size of peas. A specimen of *Favosites* was extracted from one of these beds.

In the hollow left by the removal of the limestone only one small exposure of that rock is now visible. It shows about a foot of light-grey crystalline limestone, somewhat nodular and concretionary, and apparently sheared and disturbed, overlain by 6 feet of olive-green mudstones, containing flattened nodules of blue-hearted tough argillaceous limestone, and dipping northward at 20°. These mudstones with nodules evidently form the base of the Wenlock Shales.

These basement-beds are again well-exposed at the western end of the openwork, where they yielded a few fragments of graptolites, identified as of the *Monograptus colonus* or *M. dubius* type by Miss G. L. Elles, who suggests that the beds are not Wenlock but Lower Ludlow; though how this can be so is difficult to explain, since the beds are within 10 feet of the top of the Woolhope Limestone. Higher beds are to be seen at the mouth of the drift (Fig. 1), where they dip northward at 70° to 80°, and yielded *Phacops caudatus* (Brünn.), *Plectambonites transversalis* (Wahl.), and crinoid ossicles.

The materials brought out from the drift show that the beds cut through are the Wenlock Shales, the Woolhope Limestone, and the Upper Llandovery Sandstone, as might have been expected. No other rocks were seen on the tips, though it is possible, as will appear later, that Archæan rocks were reached. A specimen of shale collected from this debris by Professor E. J. Garwood shows a graptolite, which has been identified by Miss Elles as *Monograptus flemingi* (Salt.); another graptolite she suggests is *M. vulgaris*, Wood, or *M. dubius* (Suess). A piece of calcareous grit yielded *Petraia* sp. Unfortunately the drift descends at a slight angle from the horizontal, and in September, 1915, was derelict and full of water. It was therefore impossible to make any examination or measurements of the beds cut through, and no particulars appear to have been recorded while the exploration was in progress.

From the details given above the identity of the rocks as Silurian is put beyond doubt. But the structure of the ground is revealed more clearly by the record of the boring than by the surface exposures. There is, however, strong suggestion of faulting in the manner in which the outcrop of the Woolhope Limestone along the northern side of the ridge comes to an end both eastward and westward. The outcrop commences abruptly about 120 yards north-west of the old Corton quarry (Fig. 1). It then runs obliquely up the ridge through an old overgrown limestone quarry, crosses the Folly Farm lane, and then traverses the long openwork already described till it reaches the eastern boundary of Nash and Caen Wood, where the quarrying seems to have stopped. But the strike of the beds exposed at the western end of the openwork would carry the limestone outcrop down the slope again towards the foot of the ridge, where an attempt appears at some time to have been made to reach it by shafts, one of which can be seen just within the northern edge of the wood some 200 yards to the north-west. It is therefore probable that the disappearance of the limestone in each direction, after a course of only 800 yards, is due, not to thinning out, but to faulting. This supposition is confirmed by the evidence of the boring.

The boring (Fig. 2), which was begun on April 9, 1912, and abandoned in the following autumn, is situated on the Wenlock Shales, a few yards north of the outcrop of the Woolhope Limestone. The following is the complete record as furnished by the firm who carried out the work; for the classification and grouping of the beds and for notes in square brackets the responsibility is mine:—

BORING FOR COAL AT FOLLY FARM, PRESTEIGN.

New Series 1 in. Ordnance Map, Sheet 180 (Knighton); 6 in. Map, Radnorshire, 25 N.E.; Geological Map (1 in.), 56 N.E.; lat. 52° 15′ 54″, long. 3° 0′ 2″. Boring commenced April 9, 1912, abandoned before October 7, 1912. Dip 55°, decreasing downward to 20°.

	Thickness.		*Depth.*	
	ft.	in.	ft.	in.
Wenlock Shales:—				
1. Yellow clay [sandy, full of stones]	11	6	11	6
2. Soft yellow grey shale	3	6	15	0
3. Soft grey shale	2	0	17	0
4. Grey shale and hard balls	12	6	29	6
5. Grey shale	0	3	29	9
Woolhope Limestone and Shales:—				
6. Grey limestone, broken [*Woolhope Limestone*]	20	3	50	0
7. Grey shale with hard balls of limestone	4	4	54	4
Upper Llandovery Sandstone:—				
8. Hard red grit with soft joints	1	8	56	0
9. Red-grey sandstone with lime and white pebbles	10	0	66	0
10. Red-grey sandstone with pebbles and vertical joints	10	6	76	6
11. Red-grey sandstone with shale and pebbles	17	6	94	0
12. Reddish-grey sandstone	4	0	98	0
13. Reddish-grey sandstone with pebbles and pieces of grey shale	6	0	104	0
14. Reddish-grey sandstone and pebbles	10	6	114	6
15. Grey shaly sandstone and pebbles	10	6	125	0
Longmyndian (?):—				
16. Red-grey sandstone with pebbles and beds of green-grey sandstone	10	0	135	0
17. Red-grey sandstone with white joints	6	6	141	6
18. Hard red-grey sandstone with white joints	1	0	142	6
19. Soft grey sandstone	5	0	147	6
[*Fault*]				
Wenlock Shales:—				
20. Soft grey shale	7	6	155	0
21. Grey shale with spar veins	9	0	164	0
22. Grey shale with white spar veins [*Phacops longicaudatus* and *Monograptus*]	46	6	210	0
23. Grey shale with spar veins	10	0	220	0
24. Grey shale with spar veins and partings	5	6	225	6
25. Grey shale with white spar veins	9	6	235	0
26. Grey shale with spar veins and partings	29	0	264	0
27. Grey shale	6	0	270	0
28. Grey shale with 3 in. bed of sandstone	4	0	274	0
29. Grey shale	9	0	283	0
30. Grey shale with sandstone 1 inch thick	1	0	284	0
31. Grey shale	7	0	291	0
32. Grey shale with black markings	9	0	300	0
33. Grey shale with hard sandstone	16	0	316	0
34. Grey shale with thin beds of grit	11	0	327	0
35. Grey shale with beds of spar	8	0	335	0

		Thickness.		*Depth.*	
		ft.	in.	ft.	in.
36.	Grey shale and hard dark-grey grit	6	6	341	6
37.	Grey limestone	2	0	343	6
38.	Dark-grey limestone and shale partings	7	6	351	0
39.	Grey limestone	2	6	353	6
40.	Grey shale with dark-grey grit	8	6	362	0
41.	Grey shale with veins of spar	20	0	382	0
42.	Grey shale	104	0	486	0
43.	Grey shale with spar veins	6	6	492	6
44.	Soft grey shale	10	0	502	6
45.	Grey shale	5	6	508	0
46.	Grey shale with spar veins	8	0	516	0
47.	Grey shale	12	6	528	6
48.	Grey shale, broken	47	9	576	3
49.	Soft grey shale	8	3	584	6
50.	Grey shale, broken	24	6	609	0
51.	Grey shale	29	6	638	6
52.	Grey shale, broken	10	0	648	6
53.	Grey shale	29	6	678	0
54.	Fireclay	3	0	681	0
55.	Grey shale	29	0	710	0
56.	Grey shale and limestone	1	0	711	0
57.	Grey shale	155	6	866	6
58.	Grey shale, broken	10	6	877	0
59.	Soft grey shale	11	6	888	6

At the time of my first visit the boring had reached a depth of 540 feet. The cores, which were all of small diameter, ranging down from 3 inches to $1\frac{3}{4}$ inches, had been laid out in order on shelves in a small core-shed. I broke up and examined samples taken by myself from the cores at intervals of about 10 feet, but fossils were disappointingly rare. Fragments of the trilobite *Phacops longicaudatus*? (Murch.) were extracted from a core, $2\frac{1}{2}$ inches in diameter, that came from a depth of between 180 and 200 feet, and Mr. John Pringle afterwards found in the same sample a minute fragment of a graptolite, identified by Miss G. L. Elles as *Monograptus vomerinus* (Nich.) or its variety *M. vomerinus* (Nich.), var. *crenulatus*, Törnq. Traces of small brachiopods and trilobites, too imperfect for identification, were noticed at various depths. Additional samples of mudstone and limestone from the cores were brought to the Geological Survey Office in March, 1914, by a person interested, but as their depths were not known, they threw no further light on the Silurian sequence, though Mr. Pringle extracted from them some Pentamerid remains and a fragment of *Phacops*.

It is scarcely necessary to add that no part of the cores examined yielded a trace of a Carboniferous flora or fauna, and the record shows that no seams of coal were found from top to bottom. The solitary bed called "fireclay" (Item 54) can be dismissed as a band of sheared and slickensided mudstone. The wonder is that more were not recorded.

The interpretation of the section presents several difficulties. Item 1 is probably in part "made ground" or rubbish thrown down the slope from the old limestone workings, as it was said to be sandy and full of stones. In Item 4 can be recognized the mudstones with argillaceous limestone-nodules that overlie the Woolhope

Limestone in the openwork, as already described (p. 486). The thickness of the limestone itself, although amounting to 20 ft. 3 in. as cut by the boring, would, if measured at right angles to the bedding, be somewhat less, but could scarcely be reduced to 12 feet, the maximum space permissible in the openwork. It is possible, therefore, that the thickness at the outcrop has been reduced as the result of squeezing. The balls of limestone in Item 7 show that the conditions that preceded the deposition of crystalline limestone were similar to those which followed. The boring agrees with the surface exposures in showing the rapidity of the change from the grits and conglomerates of the Upper Llandovery to the shales, mudstones, and limestones of the Woolhope and Wenlock.

Item 8 forms the top of the Upper Llandovery Sandstone, and the white pebbles in the next item identify this bed with one of those exposed in the openwork. The cores, however, yielded no recognizable fossils.

But while there is no doubt that the upper beds of Items 8–19 represent the Upper Llandovery Sandstone, there is reason to believe that the lower of these beds are Longmyndian, and that a nucleus of Archæan rocks, directly underlying the Upper Llandovery, runs through the Corton ridge, probably from one end to the other. This suggestion is based on the following evidence.

Professor E. J. Garwood, during a visit at Easter, 1915, obtained from the site of the boring a sample of rock to which special interest attaches, on account of its strong resemblance to the conglomerates of the Bayston Group of the Longmyndian System. The rock is represented by part of a 3 in. core, which, with this diameter, must have come from the upper part of the boring. In the hand-specimen the rock is a pebbly tough grit, of a purple and green colour, composed of scattered subangular pebbles (up to $1\frac{3}{4}$ inches, the majority being about half an inch in length) of purplish-red quartzite approaching jasper in appearance, with others of white quartzite, set in a greenish-grey matrix of small quartz-grains, small greenish pebbles, and a greenish interstitial paste.

Under the microscope a slice of the rock (E. 11237)[1] shows that while many of the small quartz-grains are angular, others are rounded, and, as Dr. H. H. Thomas has suggested to me, appear to have been derived from the detrition of a quartz-porphyry. This is supported by the fact that one of the quartz-grains is partly surrounded by adherent glass. A few grains, about the size of the smaller quartz-grains, are of silicified banded rhyolite. The small green pebbles appear to be chloritic sediments; the interstitial paste seems to consist of chlorite and quartz, with limonitic iron oxide. The rock contains neither felspar nor calcareous matter.

A slice (E. 11236)[1] taken from one of the large pebbles of purplish-red quartzite conspicuous in the hand-specimen shows that the quartzite is thoroughly silicified, fine-grained, and contains many skeleton rhombohedra after some slightly ferruginous rhombohedral

[1] These numbers refer to the registered rock-slides in the collection at the Geological Survey Office, Jermyn Street, London.

carbonate. The purplish-red colour of this quartzite pebble is due to a slight film of red iron oxide that coats most of the grains.

Having these characters, the rock represented by this core agrees closely with some of the Longmyndian conglomerates, rather than with the softer and calcareous grits of the Upper Llandovery. The large diameter of the core and the fact that all the conglomerates met with in the borehole lie between the depths of 54 ft. 4 in. and 147 ft. 6 in. lead me to refer the specimen to some unknown position between these limits. Moreover, at 180–200 feet the core-diameter was only 2½ inches. The record is, however, not sufficiently detailed to enable the base of the Llandovery to be located, though the mention of "green-grey sandstone" in Item 16 suggests Longmyndian. I conclude, therefore, that while the upper part of the 93 feet of conglomerates, etc., is Upper Llandovery, the lower part is Longmyndian. This is not at all improbable in view of the outcropping of conglomerates of this age at Pedwardine,[1] 6 miles to the north-east, and at Old Radnor,[2] 5 miles to the south-west; and it is not unlikely that the claret-coloured pebbles in the Llandovery grits of the Corton Quarry were derived from the neighbouring Longmyndian conglomerates.

At 147 ft. 6 in. the boring passed abruptly into a thick series of grey shales with a few thin grits and sandstones. Many of the beds are described as broken and veined with spar. That these grey shales are Silurian is proved by their yielding *Phacops longicaudatus?* (Murch.) and *Monograptus crenulatus* or its near ally *M. vomerinus* at a depth of 180–200 feet. Mr. Philip Lake, to whom I am indebted for an examination of the trilobite fragments, considers that this species indicates a Wenlock horizon. Miss Elles thinks that the graptolite shows the beds to be low in the Wenlock Shales. It would seem, therefore, that the grey shales from 147½ feet downward must be regarded as Wenlock Shales, and that the boring passed into them from the Longmyndian through a fault (Fig. 2). The 12 ft. limestone (Items 37–39) is probably a sporadic band and can hardly be the Woolhope Limestone, as it is underlain, not by the Upper Llandovery Sandstone, but by 535 feet of what are presumably more Wenlock Shales.

On this hypothesis a section through the borehole might be represented diagrammatically as in Fig. 2.

It is improbable that the dip of 55° seen in the exposures of the Upper Llandovery Sandstone close to the borehole prevails underground. The dip as seen in the cores below 147½ feet seems to vary from 20° to 30°. From these rather meagre data the minimum displacement of the fault may be estimated at $888\frac{1}{2} - 29\frac{3}{4} = 858\frac{3}{4}$ feet, a throw that would carry down the Woolhope Limestone to some position below the bottom of the borehole. And as the Woolhope Limestone, Upper Llandovery, and supposed Longmyndian in the boring overlie Wenlock Shales, the fault must be an overthrust from the south. The thrust-plane, which would reach the

[1] A. H. Cox, "The Pedwardine Inlier": Quart. Journ. Geol. Soc., vol. lxviii, 1912, p. 364.

[2] C. Callaway, Quart. Journ. Geol. Soc., vol. lvi, p. 511, 1900.

surface along the foot of the ridge, accounts for the disappearance of the Woolhope Limestone outcrop in both directions.

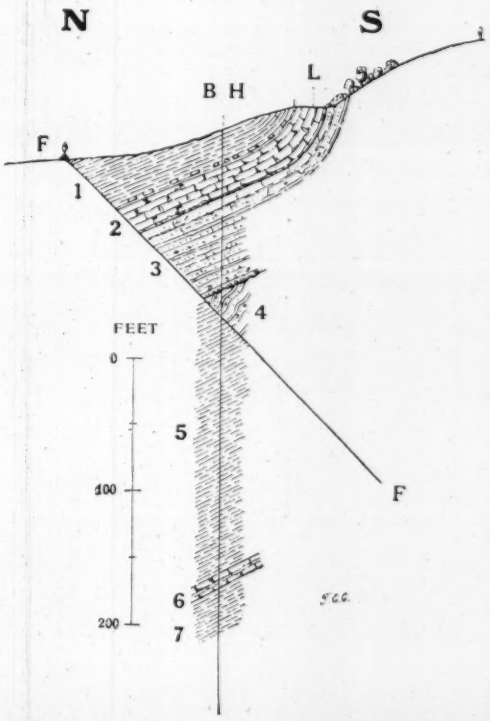


FIG. 2.—Vertical section, in a north and south plane, of the upper part of the Folly Farm Borehole, Presteign. L, lane; B H, borehole; F-F, overthrust fault; 1, 5, and 7, Wenlock Shales; 2, Woolhope Limestone and Shales; 3, Upper Llandovery Sandstone; 4, supposed Archæan (Longmyndian); 6, 12 ft. limestone-band.

The Folly Farm boring and drift are not the first nor the only recent attempts to find coal in the Silurian rocks of Presteign. Half a mile farther west, and 350 yards east of Caen Wood House, a shaft was begun in 1910, in the hope, as I was informed, of finding work for local labour by the setting up of a new industry. The debris from the shaft consists of light-blue and grey calcareous shales and mudstones. These yielded nothing but an *Orthis* and a few fragments of ill-preserved graptolites, doubtfully identified by Miss Elles as *Monograptus dubius* (Suess) or *M. colonus* (Barr.); but the evidence is perhaps scarcely sufficient to confirm the suspicion that the beds are Lower Ludlow.

The operations at the Folly Farm have not added so much to our knowledge of the local geology as might have been expected, but the boring shows the existence along the northern foot of the ridge of at least one important strike-fault, having the effect of thrusting older

rocks from the south over newer. The fossils yielded by the mudstones in the borehole are few in number, but such as can be identified suggest a low Wenlock Shale horizon for the deeper beds. If the core believed by Professor Garwood to be Longmyndian is correctly identified, the Upper Llandovery Sandstones of the Corton ridge rest directly upon a nucleus of Pre-Cambrian rocks.

II.—Notes on new and imperfectly known Cretaceous Polyzoa.

By R. M. Brydone, F.G.S.

(*Continued from the April Number, p. 148.*)

(PLATE XXXII.)

BESIDES the series of *Membraniporellæ* last described there are several other Cribrilinidæ which develop a secondary aperture in the same way, and the next four species are instances.

Cribrilina transita, sp. nov. (Pl. XXXII, Fig. 1.)

Zoarium unilaminate, adherent.

Zoœcia of medium size, average length ·7 to ·75 mm.; primarily they are of the usual type with low slightly arched side walls and arched front walls springing from the edges of the side walls, and traversed by radiating furrows pierced in their outer half by short and sometimes fairly broad slits, while at the inner ends there are preserved very irregularly remains of a system of one or two longitudinal rows of punctures; six rows of paired furrows with or without an unpaired one in the centre line seem to be the general standard; the aperture is roughly semicircular and its anterior lip bears four tubercles; in the secondary stage the side walls thicken and rise, filling up the spaces between the front walls, but only coalescing at occasional intervals; the secondary aperture is formed as usual from a denticle in the centre of the posterior lip of the primary aperture which is produced over this aperture as a flat wide bar, from the end of which (and from the sides of the primary aperture) there arises very steeply a thick ring leaving two slits on either side of the denticle and embracing the front part of the oœcium, on which the ring is flattened out somewhat angularly and bears two small pores in the angles.

Avicularia small beak-shaped, narrow, and elongated, with strong cross-bar close to the rounded end; a pair are generally placed on either side of the secondary aperture with their beaks directed inwards and generally more or less downwards and merging into the ring surrounding the aperture; others are scattered irregularly over the side walls.

Oœcia large, globose, with small apertures cut well back, very constant in occurrence.

This species is the only one in the group to show Cribriline perforation, and this fact and its tuberculated primary aperture suggest relationship to *Cribrilina furcifera*, Bryd.,[1] which itself provides a half-way stage between this type of secondary aperture and a simple aperture. It occurs quite rarely in the *Uintacrinus* band of Hants and Sussex.

[1] Geol. Mag., 1910, p. 391, Pl. XXX, Figs. 6–8.

Cribrilina T-formis, sp. nov. (Pl. XXXII, Figs. 2, 3.)

Zoarium unilaminate, adherent.

Zoœcia rather small, average length ·55 mm.; primarily they are of the usual type with very low side walls and rather strongly arched front walls traversed by radiating wholly imperforate furrows and a distinctly concave posterior lip to the aperture which is widely lenticular with a broad flat anterior lip; the furrows are very shallow and sometimes cannot be detected over a whole zoœcium; eight pairs seem to be the standard; in the secondary stage the side walls rise to a level slightly above the edges of the front walls and coalesce partly, but not wholly; a denticle forms on the posterior lip of the aperture and develops into a short rather narrow process stretching upwards at a low angle over the aperture and then giving off two branches, one on either side, at right angles to it, which curve downwards and form the posterior lip of the secondary aperture, whereby hiding the primary aperture; finally, the outer edge of the anterior lip of the primary aperture is produced forwards and raised slightly to form the thin anterior lip of the secondary aperture, which is in a highly inclined plane. When the light is from the foot of the zoœcium the anterior secondary lip, if formed, may be, and the primary anterior lip, if the secondary one has not been formed, is almost sure to be, invisible in shadow, and the zoœcium appears to end abruptly in a suspended T, which is very distinctive.

Oœcia scarce, rather flatly globose, rather large in proportion, with a wide aperture cut back rather sharply and squarely; sometimes the anterior lip of the secondary aperture rises and embraces the greater part of them.

Avicularia small, beak-shaped, with spatulate anterior ends when well developed, but accessory beak-shaped avicularia vary so much in a single zoœcium, according to their opportunities for development and their state of preservation, that no importance can be attached to variations in their appearance; they are scattered irregularly along the side walls, but tend to occur in pairs pointing towards the aperture from below and just touching the anterior lip.

This species occurs in the zone of *Offaster pilula* in Hants and Sussex and does not appear to survive that zone, nor in those counties to have any successor in the (restricted) zone of *A. quadratus*, but in the top beds of that zone in Suffolk it is succeeded by

Cribrilina Bramfordensis, sp. nov. (Pl. XXXII, Figs. 4, 5.)

This species is so closely allied to the preceding one that it is most easily described by enumerating the differences between them. *C. Bramfordensis* differs from *C. T-formis* in its greater size (average length ·8 mm.), its furrows deeply and squarely cut at the outer ends and more numerous (nine or ten pairs being a minimum, while the numerous small ones which can sometimes be detected round the anterior end, coupled with the increase in numbers which automatically accompanies any accidental increase in length, make it difficult to put any limit to the number that might be met with), the abundance of oœcia which are regularly overridden by the wide

anterior lip of the secondary aperture, and the higher angle of rise of the anterior lip of the secondary aperture and the low angle of the plane of the secondary aperture when no oœcium is present. The sum of these differences is not over-convincing, but I think it is just sufficient to support a specific distinction which marks a substantial difference both in horizon and area.

The species occurs freely at the top of the (restricted) zone of *A. quadratus* at Bramford, Suffolk, and there are indications that it occurs rarely in the Weybourne and Trimingham Chalks.

MEMBRANIPORELLA SUBCASTRUM, sp. nov. (Pl. XXXII, Fig. 6.)

Zoarium unilaminate, adherent.

Zoœcia small, average length ·6 mm.; primarily they are of the usual type, with low, slightly arched side walls, arched front walls pierced by four or five pairs of short, narrow, radiating slits, and a semicircular aperture; in the secondary stage there is the usual formation of a secondary aperture from a denticle appearing on the posterior lip of the primary aperture and from the uprising of the latter's sides; the side walls rise and thicken as usual and fuse with one another and the margin of the secondary aperture and the oœcia so as to form a broad network, enclosing and raised above the front walls and encroaching on them so as to partly or even wholly cover up the slits, and featureless except for (1) the secondary aperture, which is more or less horseshoe-shaped with a strong tendency to a small denticle on the posterior lip, and the anterior lip formed mainly by the edge of the oœcium, which though inconspicuous is very regularly present; (2) the apertures on the side walls of small avicularia merged in the general mass and present fairly regularly at the lower corners of the secondary aperture and also irregularly elsewhere; the edges of the secondary aperture run a little way up the oœcium, but do not apparently unite across it.

Oœcia large in proportion, rather flatly globose, with aperture only slightly cut back.

This species is in nearly every respect an ill-defined ancestor of *Membraniporella castrum*, Bryd.,[1] the latter is readily distinguishable by its more numerous and conspicuous slits in the front wall, and its curious cavity in the posterior lip of the secondary aperture, which is indicated in the original figure, though not referred to in the original description, and is very useful for rapid diagnosis. A figure of an admirable specimen of *M. castrum* is given for comparison. *M. subcastrum* occurs rather scantily in the zone of *Marsupites* and the subzone of *E. scutatus* var. *depressus* in Sussex. Specimens are usually very obscure.

MEMBRANIPORELLA GABINA, sp. nov. (Pl. XXXII, Fig. 8.)

Zoarium unilaminate, adherent.

Zoœcia narrow, but rather long, average length ·75 mm.; the side walls are almost common, only faint traces of a separate origin being left, and are wide, especially at the ends, and the arched front wall appears to be laid on them and to overlap their edges considerably at

[1] GEOL. MAG., 1909, p. 398, Pl. XXII, Figs. 4, 5.

the anterior end; the aperture is heel-shaped with a tiny denticle on the posterior lip, but it is often rendered more or less rectangular by the intrusion of the edge of the oœcium at the anterior end; along the edges of the front walls there are more or less paired openings of varying size, a long pair about the middle of the front wall being fairly regular in occurrence.

Oœcia large, globose, and very flat; I have only seen them with the shape of the aperture obscured or hidden by the margin of the zoœcial aperture.

Avicularia. — Small accessory avicularia with arrowhead-shaped apertures when well preserved occur very consistently in pairs beside or just above the zoœcial aperture and pointing towards it, while irregularly placed examples also occur.

This species occurs at the junction of the zones of *A. quadratus* and *B. mucronata* in the Isle of Wight and in Hants, but is very rare. It is obviously not a *Membraniporella* in any ordinary sense, but it appears at an horizon at which the Cribrilinidæ were unusually active in development, and it is so simple in structure and so closely analogous to many Cribrilinidæ, e.g. *Membraniporella tæniata*,[1] that I regard it as a highly aberrant *Membraniporella*.

CRIBRILINA REPLETA, nom. nov. (Pl. XXXII, Fig. 9.)

Syn. *Cribrilina suffulta*, Bryd., GEOL. MAG., 1913, p. 437, Pl. XIV, Fig. 5 only.

I have come to the conclusion that my so-called "coarse form" of *Cribrilina suffulta* cannot, owing to its erect side walls almost fused together, be properly united with *Cribrilina suffulta*, whose zoœcia are typically pyriporiform and quite separate. The relationship between the two is, however, so very close that each is liable to display here and there a considerable measure of the distinguishing character of the other. I have figured an exceptionally well-preserved specimen which shows that the tubercles on the anterior lip are typically four in number, long and tapering, but very brittle. *C. repleta*, like *C. suffulta*, is nearly related to *Semieschariporα interrupta*, D'Orb., which is distinguished from them by an aperture longer than its width.

CRIBRILINA GALANTHIS, nom. nov.

Syn. *Cribrilina Gregoryi*, Bryd., GEOL. MAG., 1913, p. 437, Pl. XIV, Fig. 3 only.

I have also come to the conclusion that my so-called "coarse form" of *Cribrilina Gregoryi* should also be specifically distinguished. It differs from *C. Gregoryi* in the tuberculation of the anterior lip of the aperture, which is very indistinct, but I now think consists of traces of four tubercles only as in *C. repleta* (*supra*). It also differs in a strong tendency to squareness in the shape of the outer pair of the perforations in the front wall. Specimens occur occasionally in the lower part of the subzone of *E. scutatus* var. *depressus* which are very near *C. Gregoryi*, but are not definitely that species, and may perhaps be referred to this.

[1] GEOL. MAG., 1917, p. 50, Pl. III, Figs. 3, 4.

EXPLANATION OF PLATE XXXII.

(All figures × 12 diams.)

FIG. 1. *Cribrilina transiens.* *Uintacrinus* band. Brighton. Broughton, Hants.
,, 2. ,, *T-formis.* Subzone of abundant *Offaster pilula.*
,, 3. ,, ,, Subzone of *E. scutatus* var. *depressus.* Rottingdean, Sussex.
,, 4, 5. *Cribrilina Bramfordensis.* Zone (restricted) of *A. quadratus.* Bramford, Suffolk.
,, 6. *Membraniporella subcastrum.* Subzone of *E. scutatus* var. *depressus.* Rottingdean.
,, 7. ,, *castrum.* Trimingham.
,, 8. ,, *Gabina.* Zone (restricted) of *A. quadratus.* Freshwater, Isle of Wight.
,, 9. *Cribrilina repleta.* Zone of *M. cor-anguinum.* Soberton, Hants.

III.—The Volcanic Eruption of 1913 on Ambrym Island, New Hebrides.

By Rev. M. Frater.

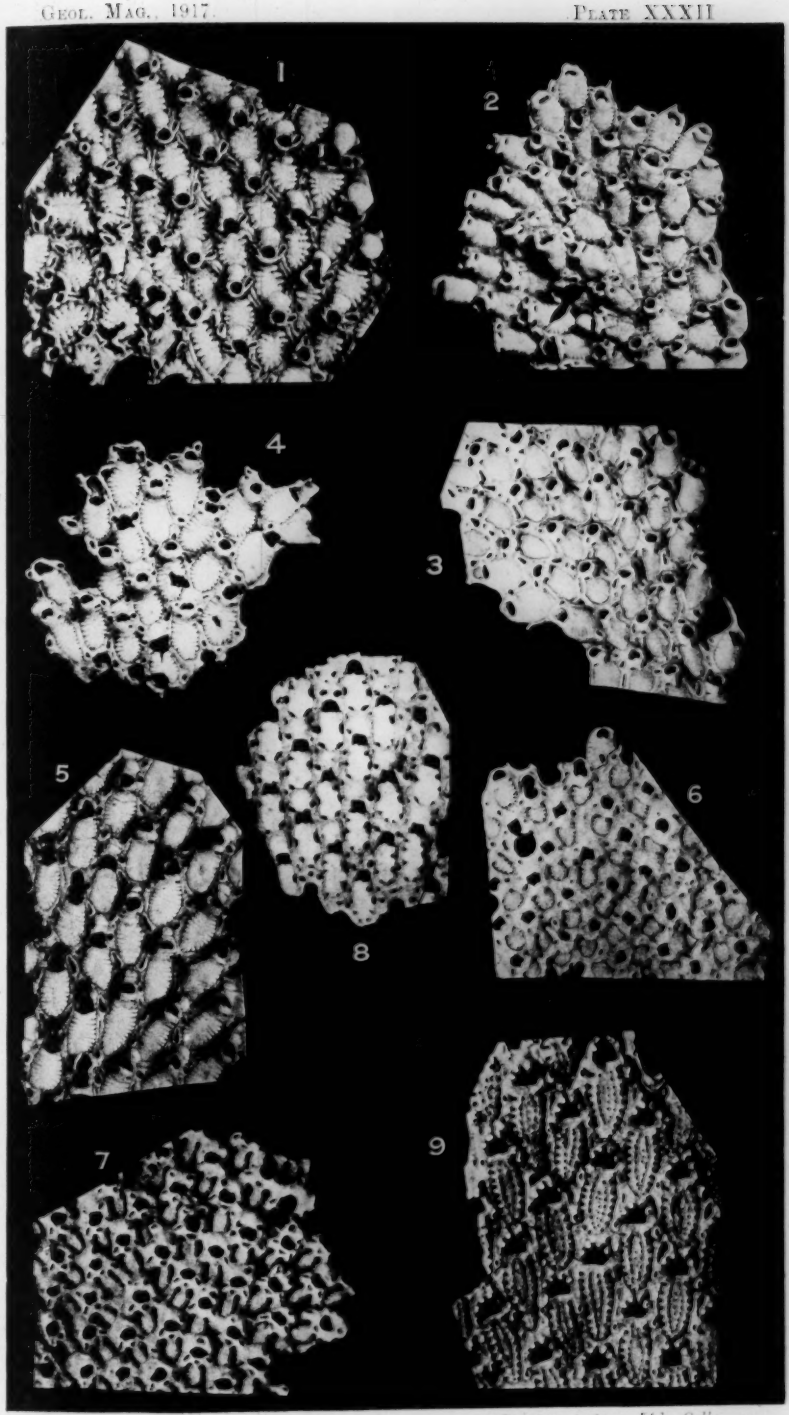
(Communicated by Professor J. W. Gregory, D.Sc., F.R.S.)[1]

THE New Hebrides group of islands was first fully made known to Europe by Captain Cook, who in the year 1774 spent forty-six days among them. Situated in the Southern Pacific, about 1,400 miles N.E. of Sydney, the total number of islands is nearly eighty, the largest of which has a coastline of 200 miles. The islands are mainly of volcanic origin and lie in a direction from S.S.E. to N.N.W. Volcanic action is almost exactly in the direction of the group of islands, and a line drawn from the volcano of Tanna in the south to the volcano of Tinakula in the north, a distance of 600 miles, would pass through the volcanoes of Lopevi, Ambrym, Ureparapara, and the boiling springs of Vanua Levu.

The line of volcanic activity which stretches across the Pacific Ocean runs through the New Hebrides Islands. Entering the Pacific from the direction of Java, the volcanic belt passes through Timor and extends to the large island of New Guinea, where it bifurcates. New Guinea seems to be a central focus from which the lines of fissure girding the Pacific radiate; one line goes northwards through Formosa and Japan, and the other southwards through the Solomon Islands, New Hebrides, New Zealand to Mount Erebus in the Antarctic Ocean.

[1] [The MS. of this paper was left with me by the Rev. M. Frater on his return to the New Hebrides for publication with some supplementary notes on the eruption after the arrival of his collection. The specimens have been kindly sent me by Admiral Parry, the Hydrographer of the Admiralty, and some account of them will be included in the Report on the Eruption to be published by his Department. This publication, however, may not be issued until the end of the War. Hence, it seems advisable to publish Mr. Frater's interesting account of the eruption without further delay. Mr. Frater acted as guide and interpreter to Commander Hancock during the resurvey of Ambrym after the eruption.—J. W. G.]

[The geological and petrological description of the Ambrym eruptions, by Professor J. W. Gregory, will appear in the December Number, with a Map of the Island.—Edit. Geol. Mag.]



E. M. Reglone, Photo. Bemrose & Sons Ltd., Collo.

Chalk Polyzoa.

The volcanoes in the New Hebrides group work in sympathetic agreement. Tanna volcano is the Stromboli of the Southern Seas. The eruptions of this volcano are still heard as in the days of Captain Cook. There is the "pillar of smoke" by day and the "pillar of fire" by night. It is the great lighthouse of the South Pacific. Like a revolving light it bursts out every three or four minutes with great brilliance. A few years ago the regular explosions suddenly ceased. The natives became alarmed; they had become accustomed to regard the volcano as the safety valve of the district, and they had sufficient knowledge of mechanics to understand that the closing of a safety valve is as dangerous in a volcano as in a steam-engine. In company with a crowd of natives, the resident missionary climbed to the edge of the crater and discovered that the walls had collapsed and choked the "fire". But no sooner had Tanna closed down than the volcano on Ambrym, 300 miles northwards, became more active. The eruptions from Ambrym, which had hitherto been spasmodic and irregular, now took place at regular intervals, glowing at night with an intermittent light resembling the flashing light of a lighthouse. Tanna remained quiescent for a few weeks, and then, with a convulsive roar, the imprisoned giant broke its bonds and awoke to life. The clock-work regularity of the Ambrym volcano ceased and the eruptions again became uncertain and spasmodic.

The same sympathetic relations which exist between Ambrym and Tanna also govern the workings of the Ambrym and Lopevi volcanoes. Situated on neighbouring islands, only 25 miles apart, their operations can be watched together. Violent activity in the one is almost invariably answered by outbursts in the other.

The destructive eruption of the Ambrym volcano with which this paper deals occurred in December, 1913. Named Mount Benbow, after one of the British warships which visited the group in the early days of European settlement, the lofty cone of the Ambrym volcano rises from the centre of an extensive ash plain, over 2,000 feet above sea-level. In the neighbourhood of Mount Benbow the ash plain is studded with a series of extinct craters, occasional puffs of steam being the only indication of the pent-up fire beneath. The ring-shaped crater wall which encloses the plain, like a wall of circumvallation, first led the survey party of the warship whose name the volcano bears to the now generally accepted conclusion that the ash plain is the basal wreck of a much loftier volcanic cone which was shattered by a volcanic eruption, and that the island of Ambrym, with its volcanic soil, now remains as a memorial to the destroyed volcano. For untold centuries Mount Benbow had been at work puffing out steam which at night reflected the glare of the molten lava bubbling within the crater walls. So accustomed had the natives become to its presence that the frequent outbursts occasioned no surprise. They cultivated the soil up to the edge of the ash plain at the base of the volcano. But all unknown to the natives, and to the French and English residents who had their homes on Ambrym, there stretched from east to west across the island a belt of volcanic fracture. On this fissure,

hidden in many places, underneath a wealth of tropical vegetation, stood the Presbyterian Mission Station, with its commodious and well-appointed hospital. The site was one of the beauty spots of the New Hebrides Islands. The hills around were covered with the luxuriant vegetation of the tropics. Adorning the extensive clearing which encircled the mission station, were wide-spreading banyan-trees which had weathered the storms of centuries. Little did the promoters of the Medical Mission imagine that they were building over a slumbering volcano. Beyond the shape of the valley, which was undoubtedly crateriform, there was nothing to indicate that underneath the calm and luxuriance of external nature the forge of Vulcan was being set up. In the light of recent events there can be no doubt that the station was standing in the crater of an old volcano; but it showed no trace of any recent eruption, and among the natives no memory of any such catastrophe survived in the traditions of the district. Countless generations, too, must have elapsed in the populating of the crowded villages which thronged the district, and in Captain Cook's day the population was greater than it now is. The symbolism and system of sorcery which had grown around the native mythology was more intricate and subtle than that which flourished in most of the other islands, and pointed to a long succession of ages since fire had visited the district.

In December, 1913, the age-long sleep of the extinct volcanoes near Mount Benbow was broken, and from numerous thunder-throated vents the island was torn and rent with convulsive explosions. The eruption was heralded by a series of premonitory earthquake shocks. One of them, which occurred about a month before the outbreak, was the most severe in the memory of the natives. Immediately preceding the eruption, the shocks increased in frequency and severity until the solid earth reeled and tottered. The hospital buildings rocked like a ship at sea. The natives, in their manner of speech, said that Ambrym danced. Then there was seen to rise from the extinct craters a dense cloud which shot up into the air and spread out in all directions like a gigantic mushroom. Tremendous explosions followed each other in rapid succession. Blacker and larger grew the cloud until it lay like a London fog over the entire island. The erupting volcanoes followed the line of volcanic weakness. Beginning at the extinct craters in the centre of the island, the line maintained a westerly direction and every few miles a new volcano burst out. From the neighbouring island of Paama, where an unobstructed view of the eruption was obtained, its rise and progress could be watched. In one place which seemed to be a centre of disturbance, six volcanoes had formed within a short distance of each other. During the night the track of the red-hot lava could be seen like the trail of a serpent. Every outbreak brought the eruptions appreciably nearer the hospital until in the early morning, twelve hours after the first outbreak, the advancing flare could be seen behind the hills which encircled the Mission Station. At daybreak a dense black cloud was seen about a mile behind the station, but the hospital staff imagined that the bush had been set on fire by a lava stream. While they were watching it,

a neighbouring trader who had two boys in the hospital arrived by motor-launch and reported that it was a volcano which had burst out. At the same instant, terrified natives from the inland villages arrived with the news that the earth had opened some distance up the valley and the molten lava had formed a lake of fire. They told of villages blown up, of villages surrounded by fire, of hairbreadth escapes from death. Most of the adults carried children. Large numbers of old people had been left behind to perish. Preparations were at once made for the removal of the patients. One of them, the wife of a missionary, had given birth to a child a few hours before, and she with her new-born son were the first to be rescued from the doomed hospital. Another lady, the wife of a planter, had her baby born when on the way to a place of safety. A motor-launch was filled with the more helpless patients and sent, under the charge of one of the assistants, to Malekula, an island 15 miles away. The launch had scarcely left the beach when the engine stopped; a valve had jammed. After watching for a little the medical superintendent rowed off in a small boat and, locating the trouble, banged the obstinate valve down with a hammer. As he was returning to the shore the doctor saw his wife and a number of hospital patients racing for their lives along the beach; the crisis had come one step nearer. At this moment the doctor went back to the station; he could see one side of a hill belching fire, not a quarter of a mile away; he set his teeth and made for the station and, when he had ascertained that the place was clear, made a race back to the boat on the beach, while the ground heaved and swayed beneath him. At the boat landing another problem confronted him; the sea was boiling hot, and the boat lay out a little from the beach. Fortunately, a box was found, and throwing it down at the edge of the water, the doctor sprang from it into the boat. The native crew pulled with might and main, but they had only gone a short distance when the earth reeled with a great thunder, and looking back the doctor saw the fragments of his house and hospital hurled into the air. A volcano had burst out in the middle of the hospital grounds, and from the place where the hospital stood a column of steam was shot up with such prodigious velocity that in less than a minute it had risen 20,000 feet above the level of the crater. At this elevation the particles of finely powdered rock were caught by the prevailing winds and carried great distances out to sea. A steamer running between Sydney and Fiji, several hundred miles away from the islands, had her decks covered with minute particles of volcanic dust. On the surrounding islands it rained ash and cinders, and vegetation was sheathed in a thick layer of sulphurous ash. Besides this a sticky mud rain fell, a mixture of condensed steam and ejected dust. The compressed steam rushing at lightning velocity through the main vent and the fissures in the sides of the crater formed a gigantic hydro-electrical machine and charged the atmosphere with electricity. Every few seconds there issued from the murky cloud, which hung like a pall over the island, flashes of vivid lightning. The French steamer *Pacifique* arrived on the scene four days after the eruption and, owing to the abundance of atmospheric electricity, could not get its wireless to work.

About two hours after the outbreak at the Mission Station, the eruption, still following the same line of weakness, made a further leap and reached its last stage. Out to sea, at a distance of about a mile from where the hospital stood, where there was a depth of 25 fathoms of water, a submarine volcano burst out and formed a crater cone 330 feet high, which was afterwards named "Sealark Hill" after the survey ship which was sent by the British Admiralty to make a survey of the island. The enormous quantities of "ejecta" which poured out of this volcano soon formed a connexion with Ambrym Island and added a considerable area to its extent. On the abatement of the volcano which swallowed the Mission Station, it was found that a lagoon, connected with the sea by a narrow channel, had formed in the crater, covering the entire mission compound. Over the place where the hospital stood there is a depth of 8 fathoms of water, and from the soundings made by H.M.S. *Sealark* it was ascertained that the lagoon forms a safe, land-locked hurricane harbour for ships of shallow draught, provided, of course, no other volcano bursts out. To most mariners, however, the shelter provided by the crater of a volcano from the violence of a hurricane will look like a choice between Scylla and Charybdis and, very probably, they will prefer to take the risk of the element they know best. The first time an attempt was made to enter the lagoon the mud around the edge was still boiling and steam was rising from all over the surface of the water. The sounding line was kept going and at 20 fathoms it dropped into the burning lava where the lead attachment was melted. While the sailors rested on their oars at the entrance of the lagoon a submarine explosion startled the occupants of the boat and quenched the desire for further exploration. It was no place for either men or angels to linger.

The configuration of the surrounding country has entirely changed. Only by the aid of instruments is it possible to locate the position of any particular place. Across the extensive valley which lay behind the hospital a range of hills 500 feet high had been raised. So complete was the destruction of the hospital and mission buildings that not even a match was left. Thousands of acres of fertile lands had been changed to barren wastes, forests were blasted, and large numbers of lives lost. All the old familiar landmarks on the shore had disappeared, and the hills in the background were covered with a thick layer of volcanic dust.

During the night when the hospital staff was watching the progress of the fire a lava-flow reached the sea about a quarter of a mile north-east of the hospital. Quite oblivious of their danger they crossed over to have a look at it. They saw the stream of molten metal,[1] like an incandescent avalanche, sweeping everything before it. Masses of rock and vegetation were borne along on its surface; it crashed through the big banyan-trees and teakwood giants; the trees were tossed into the air and rebounded like indiarubber balls. On the level ground near the coast the stream was travelling at the rate of four miles per hour, was 200 yards broad, and, on being traced after the surface of the lava had solidified, was found to have its

[1] This use of the term is consistent with that by miners and civil engineers.

source in a fissure eruption in the centre of the island. It is not easy to describe the kind of cauldron that was formed when this huge mass of molten metal reached the sea; it plunged into it with loud detonations; the red-hot lava was shivered like melted glass into millions of particles; gigantic blisters were formed, exploding like miniature volcanoes. The crackling noise was deafening, and to such a height was the column of steam and ash shot up that the spectators on a neighbouring island, twenty miles away, imagined that a new volcano had burst out on the sea-shore. The sky was darkened and, for miles around, the sea was covered with dead fish and debris of all sorts. Enormous quantities of pumice-stone floated on the water and covered the sea for miles.

By the time H.M.S. *Sealark* arrived in the islands the surface of the lava streams had solidified and it was possible for the Survey party to trace the flows from the shore to their sources in the interior of the island. A belt of fracture, marking the line of volcanic activity which runs through the island, was discovered, and on this line of weakness all the old and new volcanoes are placed. At the opposite end of the island, where volcanic action has become almost extinct, a considerable amount of vapour rises to the surface through fissures in the ground. From some of the fissures flows water hot enough for the natives to cook their yams. In their journeys across the island the natives use these places as camping-grounds where they can procure hot water without the labour of kindling fires. But of recent years, due possibly to the exhaustion of volcanic energy in the south-east part of Ambrym, the number, as well as the heat, of these hot springs is diminishing. Standing on an elevation near one of the volcanoes on the ash plain it is possible for the eye to follow the belt of fracture to the other end of the island, and then with an intervening channel of ten miles rises the lofty cone of the Lopevi volcano, indicating that it lay in the same line of weakness on the earth's crust.

During the visit of the Survey party, Mount Benbow was in violent eruption, and presented a beautiful sight. Every few minutes, and sometimes almost continuously, eruptions took place, and, with every explosion, gigantic clouds of dust and ash of crebriform shape were shot up to a great height. From the anchorage of H.M.S. *Sealark*, at the north end of the island, the officers measured the height of the column and found it to be 12,000 feet above the lip of the crater.

The mouth of the crater was one mile long and three-quarters of a mile broad. Standing on the lip of the crater it was possible to watch operations. With bellowing noise showers of hot stones were ejected, some of which fell uncomfortably near to members of the party who approached the danger zone. Blocks of rock, torn from the walls of the vent, were hurled into the air. The heavier rocks fell back into the crater, and the smaller and lighter, carried by the winds, were piled around the crater with more or less regularity, according to the direction of the prevailing wind. The fragmental materials thus accumulated were of all shapes and sizes, from the finest powdered stone to large blocks blown out of the

crater walls. Volcanic bombs lay scattered around. They had been ejected in a pasty condition and readily took the impress of a coin. When broken the core was found to be porous, but in the passage through the air the outside had become rounded and smooth. From the lip of the crater the inner wall had a sloping dip of 1,000 feet to an extensive level plateau of what appeared to be boiling mud, from the centre of which rose another crater cone, which was partly obscured by vapour rising from the boiling mud as well as from the innumerable holes in its walls. From the inner crater came the explosions of steam and ash, but there was no possibility of looking into its interior.

Eight lava streams, of lengths varying from one to ten miles, flowed during the eruption. Some proceeded from volcanoes with crater cones, others from fissure eruptions which were marked by an absence of crater-shaped vents. The fissure eruptions ejected lava in larger quantities than the crater volcanoes, though the flow was not always from the central vent but from rents in the crater wall. So enormous were the floods of this molten metal that the lava stream pierced through the thick bush, forming tracks from 100 yards to three-quarters of a mile broad. Viewed from the sea these black cindery tracks, running inland through the dense vegetation, resembled railway cuttings, and the smell of the cooling slag tended still further to confirm the resemblance. Sometimes, the lava stream parted and enclosed timber-covered islets. The trees on these islets survived, like island stations on a railway line. The only trees which seemed to withstand the first onset of the avalanche were the giant she-oaks. The molten metal flowed round these forest kings and clasped them in its embrace. The trunks were slowly consumed and deep cylindrical holes were left, at the bottom of which could be seen the glowing red lava. These holes, ranging from 10 to 20 feet deep, assumed the shape of the tree-trunk, and on the sides of the encrusted lava could be seen the impress of the tree. The cooling of the lava must have been very rapid, as the bark of the trees on the edge of the stream, where there was little depth of fire, was not even burnt, but only scorched. Here and there on the lava streams were miniature cones formed by the escape of gas and lava from the liquid interior, and these cones, some of them 15 feet high, continued to spout molten lava long after the main stream had passed. Three months after the eruption, heated vapours were still issuing from these cones. The vapours, impregnated with iron and sulphur, were acting chemically on the rocks, and produced a wealth of variegated colours in which white, yellow, and red predominated. Underneath the surface of the lava streams there seemed to exist numerous vesicular cavities in which vapour was imprisoned. The tread of the feet produced a dull, hollow sound and reverberated like the noise of a drum. Many fissures and cracks in the stream were still spouting hot vapours, and in some of the cracks the rocks were glowing within a few feet of the surface.

The lava streams assumed a variety of structures due to the amount of aqueous vapour imprisoned. Some were slaggy and ropy with a smooth, glassy appearance, others of the scoriaceous type had

S.KECHAU
S.KENONG
KUALA TEKAL
S.TEKAI
S.JELAI
KUALA LIPIS
LANNA
SIBAH
S.KRAMBIT
S.TEMBELING
LUBOK SUKUM
TEMBELING
S.LIPIS
S.CHIKA
BENTA
PULAU GUAI
TANJONG LINDONG
PULAU PRIAS
S.TEH
110
JERANTUT
JERANSONG
KUALA JERANSONG
100
LUBOK PLANG
Road to Kuantan
BATU REDAP
KUALA KRAU
S.KRAU
90
PULAU CHENGAI
S.TEKAL
KUALA TEKAL
S.PAHANG
KERDAU
Railway
80
S.SEMANTAN
TEMERLOH
70
FROM GEMAS
MENGKARAK
LEGEND
Mesozoic Granite
Gondwana Rocks
Boulder-in-Tuff Deposits
Tuffs & Lavas
Quartz-Porphyry & Granophyre
Raub Rocks
Pahang Volcanic Series
GLOSSARY
S=Sungei = River
Pulau = Island
Kuala = Mouth
Lubok = Lynn
Tanjong = Headland
Geological Sketch Map of part of ULU PAHANG
4 2 0 4 8 12 16 20 Miles

a rough and cindery appearance. The resemblance between the slag heap of an ironwork and the natural lava is very striking. Indeed, to stand on a lava-flow with the eyes shut by the side of a steam blow-hole and with the smell of the molten metal in the nostrils, it does not require a great exercise of the imagination to transplant oneself from the volcanoes of the South Sea Islands to the ironworks in the Black Country of Great Britain. Travelling over the rugged, cindery flows was attended with difficulty and danger, and the jagged edges made progress slow.

A strange phenomenon was witnessed in one of the volcanoes. After belching molten metal for two weeks, its activity gradually subsided, and apparently, from out the same vent, torrents of ice-cold water began to flow. The same phenomenon was witnessed by an old French settler in a volcanic outburst twenty years previously. From the other volcanoes abundant streams of moderately cold water gushed out and occasioned no surprise, but ice-cold water and molten metal from the same fountain seemed strange and incongruous. The floods of ice-cold water followed the same course as the lava-flow, covering the lava with a thick layer of silt and ash. A good path was formed, rendering this lava track the easiest of all the streams to traverse. Following its course it is possible to trace the lava from the sea to its place of origin at the edge of the ash plain.

The phenomena presented by the Ambrym eruptions would seem to indicate that water played as important a part in fissure eruptions, where intermittent explosions of steam were absent, as in the violent eruptions from a crater cone where explosions of steam were present. Eight lava streams were formed during the eruption; some of them had their source in overflows of lava from crater vents amid paroxysmal explosions of steam, others welled out of the earth like a fountain without the formation of crater cones and without explosions of steam. But the presence of water was as marked in the one case as in the other. In the fissure eruption which took place near the village of Meltungan streams of lava literally gushed out of the fissures without intermittent explosions of steam. These fissures were characterized by an entire absence of volcanic cones and extruded a continuous stream of molten lava which flowed for miles until it reached the sea. The lavas from these flows were impregnated with as much aqueous vapour as the lavas from crater eruptions. From other islands, 15 to 20 miles away, these lava streams could be traced by the columns of steam which rose from the cooling metal.[1]

IV.—The Pahang Volcanic Series.

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(WITH A MAP, PLATE XXX.)

(*Concluded from the October Number, p. 462.*)

Description of Tuffs and Breccias of the Pahang Volcanic Series.

BY far the greater part of the volcanic rocks of Malaya consists of fragmental deposits, which at first sight seem to be andesite-tuffs and andesite-breccias, for most of them contain abundant

[1] Dr. Gregory's description of the Ambrym eruptions will appear in the December Number.

fragments of andesitic lava. However, the majority also contain numerous fragments of quartz, some of which occur as isolated angular grains in the cement, others embedded in a very fine-grained siliceous rock, and sometimes showing rounded outlines and even bays, invaded by the siliceous aggregate. Tuffs which occur in certain localities, e.g. at Kuala Tekal, Tembeling, and Sibah near Kuala Lipis on the Pahang railway, contain the usual fragments of andesite-lava, with numerous fragments of quartz like those just described, and in addition fragments of rhyolite-lava or quartz-porphyry. It is probable that the great majority of the Pahang Volcanic Series of tuffs are formed of an admixture of andesitic, rhyolitic, and sedimentary material.

The first type to be described is an andesite-rhyolite-breccia[1] from the Benta–Kuantan road, at the 47th mile from Benta. There is no hand-specimen of this rock in the collection, but judging from the slide (Pl. XXIX,[2] Fig. 4) it is a dark-green rock, fairly fine-grained, with occasional red spots, made up of abundant fragments of andesite-lava and quartz, with occasional crystals of felspar and fragments of quartzite, set in a cement of quartz and calcite. In addition there are numerous pieces of altered rock, consisting of a fine-grained siliceous aggregate with large included quartz grains, and in one case enclosing a rectangular pseudomorph of magnetite, probably after felspar. Also there are some fragments of a highly altered rock, composed of a rather coarser quartz mosaic, with a little black iron-ore evenly distributed throughout the mass, and comparatively large irregular flakes of white mica.

The andesite-lava fragments are made up of felspar laths, usually untwinned and with a low extinction angle, set in a dark-green isotropic material which often includes large grains of magnetite. There is a greater quantity of glass in these lava fragments than in any of the andesite-lavas which have been noticed in situ. The felspar laths are bent, suggesting that the andesite fragments were hot plastic masses when they were detached from the parent body. Some of the lava fragments contain numerous cavities filled with a green chloritic mineral which is arranged in radiating fibres.

The quartz grains vary considerably in size and appearance, some being angular while others are rounded and have a corroded appearance. The quartzite fragments are stained red with hæmatite, and magnetite and hæmatite are widespread, both in the lava fragments and in the cement. The few felspar crystals which are contained in the tuff are usually broken, and in composition correspond to oligoclase-andesine.

Breccias similar to this occur outside Pahang in the south of Negri Sembilan *[3] and north of Johore *, but the rhyolite admixture cannot here be recognized definitely, and the numerous angular

[1] Described by Mr. Scrivenor in *The Geology and Mining Industries of Ulu Pahang*, Kuala Lumpur, 1911, p. 43, No. 1851, pl. xi.

[2] Plate XXIX of rock-sections, also explanation, appeared with the earlier part of this paper in the October Number, facing p. 462.

[3] An asterisk marks the names of all those places in Malaya mentioned in the text which are outside the area shown on the accompanying Map, Plate XXX.

quartz grains may be shattered fragments from the volcanic neck. They are probably not a sandy admixture brought down by streams, for the fragmental volcanic rocks of this district are interstratified with a series of shales which were at one time calcareous, and from which sandy beds are typically absent.

A volcanic breccia was found occurring as boulders at Kuala Seli* in Selangor at the 13½ mile from Kuala Lumpur on the road to Ginting Bidei (not shown on map), and reference has already been made to the rock as perhaps revealing the age of the purple quartz-porphyry which is found as boulders on the Main Range between Kuala Lumpur and Bentong.

It is green in colour and is made up of angular fragments of the following rocks; quartz-porphyry something like that occurring in situ at Jeram Gading* and as boulders in this district and on Ginting Sempak*, quartzite, and small rounded pieces of a homogeneous fine-grained siliceous rock like those which occur in the felspathic grits that are so often associated with cherts. They may be of sedimentary origin or they may be devitrified lava. There are pseudomorphs of epidote and an opaque dust which have a wavy outline, and in form resemble the altered biotite crystals in the Ginting Sempak quartz-porphyry. In addition grains of quartz make up a considerable part of the rock, some of them angular, others having a rounded corroded appearance, and broken crystals of orthoclase and oligoclase-andesine felspar are also common. There is very little fine-grained material, but amongst it can be noticed some grains of secondary epidote.

About half a mile west of Tembeling a deposit of andesite-rhyolite-breccia is exposed in the railway-cutting which is probably near a volcanic neck, for it is a coarse-grained red rock, the fragments being often more than an inch across, and consisting of quartzite, limestone, lava (both andesite and rhyolite), and crystals of felspar, quartz, and occasionally augite, the cement being quartz-aggregate, calcite, and iron-ores.

The andesite-lava fragments are well preserved, and belong to the type with a ground-mass of very small microliths of felspar enclosing well-shaped augites partly altered to chlorite, calcite and magnetite, and biotite crystals which have been bleached and have sometimes been entirely obliterated by secondary iron-ores. The rhyolite fragments are much more altered, the ground-mass now consisting of a secondary aggregate of quartz in which round bodies which were originally spherulites can occasionally be distinguished under crossed nicols. The shape of the lava fragments is very irregular, but there is no sign of a rapidly cooled margin. These lava fragments are distinct in character from the deposits of boulders in tuff which will be described later, the principal point of difference being that they are not water-worn.

Another slightly different type exposed in the railway-cuttings near Kuala Tekal may be described as an andesite-rhyolite-tuff, and in the hand-specimen it is a dark-green rock containing small black lava fragments, and crystals of felspar, quartz, and biotite, varying up to ½ cm. across.

Under the microscope the lava fragments are seen to be of two varieties, one made up entirely of felspar laths with trachytic structure, the other being very fine-grained and containing spherulites. The felspar crystals also are of two varieties—oligoclase-andesine and orthoclase. There is a good deal of dark-green chloritic material spread throughout the rock.

A similar rock at Sibah near Kuala Lipis contains a good deal of secondary epidote and mica, some of which has been formed by the alteration of augite crystals. No augite is left unaltered, but the sharply defined octagonal outline of the pseudomorphs suggests that augite was the original mineral.

Andesite tuffs without considerable admixture of more acid material are rare, but a specimen of greenstone with abundant epidote collected on the Benta–Kuantan road near the main Gondwana outcrop east of the Pahang River is more basic than those hitherto described, and contains little, if any, rhyolite material. The fragments of andesite-lava contain small augites as granules interstitial to the felspar laths. Crystals of oligoclase-andesine and augite are common, and there are a few fragments of quartz which are penetrated by epidote, and which when viewed between crossed nicols look like fragments of granophyre in which the felspar has been replaced by epidote. Fragments of an altered shaly sedimentary rock occur, and so do occasional rounded grains of corundum. Magnetite is very abundant in this rock, most of it being secondary.

Besides the above types, consisting in the main of fragments with very little fine-grained matrix, there is the compact type of tuff, in which the bulk of the rock is made up of a very fine-grained material, now of a siliceous nature.

Such deposits can only be determined as volcanic when a considerable number of the larger fragments are of felspar or, as only rarely happens, when fragments of lava can be recognized; in fact, there is an insensible gradation into a sedimentary grit. Probably many rhyolite tuffs are of this nature, and cannot be distinguished from felspathic grits. Then, again, other rocks very much resemble rhyolite tuffs, but they cannot be distinguished from partly altered rhyolite-lava flows unless some field evidence is forthcoming.

Deposits of Boulders in Tuff.

A most remarkable deposit is found in Pahang associated with tuffs and breccias similar to those already described. It consists of rounded masses of lava, tuff, acid intrusive rocks, or sedimentary rocks embedded in a fragmental matrix, the masses being very different from bombs and lapilli which are usually associated with tuffs. In several of the known exposures the boulder-in-tuff deposit passes into the usual tuff without boulders or pebbles.

Their characteristics are summed up as follows:—

1. They vary in size from a pea to over a yard across (at Kuala Tekal).

2. They are water-worn, show no sign of vesicular structure, and have not a glassy margin.

3. They are sometimes arranged in definite strata where they occur as pebbles of small size, e.g. at Tanjong Lindong.

4. In composition they coincide with the Pahang Volcanic Series rocks found in situ, including andesite-lava, rhyolite-lava, andesite-rhyolite tuffs and breccias, quartz-porphyry, and granophyre. No dolerite boulders have yet been found in these deposits. In addition to these volcanic rocks, one boulder of reticulating quartz veins was found in the Kuala Tekal section, and at Batu Redap many of the pebbles consist of a rock which should be described as a slightly felspathic grit—though it may be a fine-grained rhyolite-tuff. There is no distinction between the mode of occurrence of the sedimentary rock and the vein-quartz as boulders in the tuff, and the much more numerous boulders of igneous rocks.

The table on p. 508 gives the different localities in which the boulder deposits are found and the nature of the boulders.

Some of the boulders in tuff at Pulau Guai (see Map, Plate XXX) are of a rhyolite with numerous dark angular shale-inclusions, some of which contain crystals of chiastolite. This rock contains a good deal of calcite mixed with it.

It is very like a rhyolite-lava with shale-inclusions which occurs in situ at Pulau Chengai. Unfortunately, in the field the Pulau Chengai rock was mistaken for a conglomerate belonging to the Gondwana series, and certain other exposures near here which were named as coarse-grained quartzites may be really this same rhyolite-lava with inclusions of shale, so nothing can be said with certainty as to whether the boulder deposits of Pulau Chengai occur near the boundary of the Gondwanas and Raubs. This cannot be taken as evidence, but it will be seen from the third column of the following table that there is evidence to show that the boulder deposits occur always at a boundary of an outcrop of Gondwana rocks with Raub rocks.

The tentative theory as to their origin,[1] put forward by Mr. Scrivenor, the Government Geologist, was "that they were derived from already consolidated sheets of lava and ash, and masses of igneous rock consolidated below the surface, and that they became rounded by attrition in some way we cannot explain before they were shot up into the sea and fell back on ash being deposited on the sea-bottom".

Owing to the infrequency of exposures the field relationships of the deposit are very little known, but, in the nine districts where the deposit has been examined, the small amount of evidence that can be collected indicates that the deposit lies at the junction of Raub and Gondwana rocks. It is probable that there was an important unconformity between the Raub Series and the deposition of the Gondwana rocks, and evidence for this is afforded by the occurrence of pebbles of veined chert and Pahang Volcanic Series rocks in the Gondwana conglomerates. It seems likely that the pebbles were derived from cherts and Pahang Volcanic Series rocks of Raub age, and the fact that sufficient time elapsed after the formation of the

[1] *The Geology and Mining Industries of Ulu Pahang*, Kuala Lumpur, 1911, p. 47.

No.	Locality.	Nature of Boulders.	Remarks as to Associated Rocks, etc.
1.	Near Kuala Tekai, Tembeling River.	Tuffs andesite. Quartz-porphyry (?).	Country rock is Gondwana quartzites, etc., yet the boulder deposits contain much calcite.
2.	Pulau Guai (Pahang River).	Rhyolite - andesite - tuff. Rhyolite-lava, andesite - lava. Quartz - porphyry and porphyrite.	Up-stream from here the nearest sedimentary rock in situ is Gondwana quartzite 1½ miles away.
3.	114½ mile, railway.	Much weathered, no specimens collected.	Quartzite near 115th mile. Exposures too much weathered at and near 114½ mile to say whether Raubs or Gondwanas.
4.	Tanjong Lindong to Pulau Prias (Pahang River).	Rhyolite, andesite, and perhaps quartz-porphyry.	An outcrop of Gondwana quartzite occurs near Bulau Prias.
5.	105th mile, railway.	Andesite, trachyte, rhyolite or quartz-porphyry, granophyre.	At boundary of Gondwanas and Raubs. Granophyre is in situ in Raub Series rocks within 3 miles of this place.
6.	Kuala Jeransong to Lubok Plang (Pahang River).	Rhyolite and perhaps quartz-porphyry.	Chert is interstratified with the tuffs at Lubok Plang, also rhyolite-lava flows. The surrounding country rocks are Raubs.
7.	Batu Redap (Pahang River).	Felspathic grits, perhaps volcanic.	The railway is within a mile or so and core-boulders of quartzite are lying on limestone, so there may be a junction of Gondwanas and Raubs near here.
8.	Pulau Chengai (Chengali), Pahang River.	Rhyolite and perhaps rhyolite-tuff.	Probably near boundary of Gondwana and Raub rocks.
9.	Kuala Tekal, 87th mile, railway.	Rhyolite quartz-porphyry, and porphyrite.	Cuttings too much weathered to determine whether the sedimentary rocks belong to the Raub Series or whether they are Gondwanas.

Raub cherts for them to undergo veining before being eroded shows that the unconformity was an important one. This theory was explained in full in 1911 by Mr. Scrivenor,[1] but at that time it was thought that the chert beds formed a single separate series between the Raub and Gondwana rocks, whereas it is now known that many of the chert beds of the Peninsula are interstratified with Gondwana quartzites.

If the deposits of boulders and pebbles in tuff occur at the boundary of Raub and Gondwana rocks, it is fairly clear that they were formed during the period between them, i.e. in the period of terrestrial conditions.

Mr. Scrivenor said in 1911, that they bear resemblance to the "ashy conglomerate" of the Mendips, described by Professor S. H. Reynolds,[2] but added that after examining Mr. Scrivenor's photograph of the Pulau Guai beds (plate ix, Ulu Pahang memoir) Professor Reynolds thought that the two deposits do not agree. The bedding observed in the Pahang deposits is a point of difference from the Mendip "ashy conglomerate". Professor Reynolds gives four possibilities as to the nature and origin of the Mendip deposit, and one of them, slightly amended, is now suggested as accounting for the Pahang deposit.

The deposit of boulders and pebbles in tuff was laid down during the latter part of the unconformity which followed the Raub period, and during the subsidence when the Gondwana rocks were formed. The line from Kuala Tekai on the River Tembeling to Kuala Tekal on the River Pahang marks the position of the coastline during a pause in the depression, in which beach deposits were formed in sheltered parts of the coastline, and were mixed with volcanic ash which all this time was being deposited on the sea-floor by active volcanoes. Sufficient time must have elapsed between the beginning of the terrestrial conditions and the end of the period of formation of the beach-deposit to allow for the denudation of the considerable thickness of sedimentary rocks which must have covered the quartz-porphyry, granophyre, and other intrusions, for boulders of these intrusive rocks are common in the beach-deposit.

This theory explains the heterogeneous nature of the boulders and pebbles and their well-rounded appearance. It also explains the bedded nature of the deposit and its association at Lubok Plang with a band of chert, for it has been suggested before that chert can be formed in shallow water if the growth of Radiolaria is favoured by abundant silicates being supplied to the sea-water[3] by gases from

[1] *The Geology and Mining Industries of Ulu Pahang*, Kuala Lumpur, 1911, p. 56.

[2] Quart. Journ. Geol. Soc., vol. lxiii, p. 227.

[3] J. B. Scrivenor, "Radiolarian-bearing Rocks in the East Indies": GEOL. MAG., Dec. V, Vol. IX, No. VI, June, 1912, pp. 241–8. Mr. Scrivenor discusses the origin of the Peninsula chert, and points out that in Kedah the chert is not associated with volcanic rocks. He suggests that large quantities of silica in solution, supplied by tropical weathering of siliceous rocks, may have promoted, or helped to promote, the abundant growth of Radiolaria in shallow seas.

volcanic effusions.[1] The absence of any great quantity of sedimentary material can readily be understood, as also the fact that the boulder-in-tuff deposit often passes into a tuff devoid of pebbly material.

The theory that the boulders were deposited in water near a shore-line helps to explain a peculiar circumstance noticed with regard to the tuffs near Pulau Guai. There is a series of exposures of granophyre over a distance of 4 miles to the north of Pulau Guai, one occurring only about a hundred yards up-stream from the first boulder deposit, and all the tuffs between Pulau Guai and Kuala Tembeling contain fragments of granophyre, whilst of the many specimens of tuffs examined from Pulau Guai only one contained what might be regarded as a fragment of granophyre. At the 102nd mile on the railway there is an intrusion of granophyre, while 3 miles further north is a boulder deposit in tuff. One of the boulders consists of granophyre, and fragments of granophyre occur in the tuff at the 105th mile and in tuffs between there and the intrusion.

The granophyre was exposed by the action of denudation during the period of unconformity, and fragments of it were carried down by stream action and deposited with tuffs which were being formed by active volcanoes at the time. Evidently the shore-line moved from west to east or a little north of west to a little south of east, and this explains the change from tuffs with granophyre fragments to tuffs without granophyre fragments when going down-stream at Pulau Guai, for as soon as the outcrop of granophyre became submerged below low-tide mark it would no longer be subject to denudation.

It was hoped to include in this paper a comparison of the Pahang Volcanic Series with the older volcanic rocks of the Malay Archipelago, as described in various Dutch and German publications, but the process of translation has proved so laborious and slow that it has not been possible to compare them with the volcanic rocks of any other districts but the Goemaigebergte of South Sumatra, which are described by Dr. Emil Gutzwiller in *Mijnwezen*, 1912, *Verhandelingen*.

Comparison of the Pahang Volcanic Series with the Permo-Carboniferous Volcanic Rocks of the Goemaigebergte, South Sumatra.

There are no older acid intrusive rocks in Sumatra which correspond to the quartz-porphyries and granophyres of Pahang, nor are there any rhyolitic lavas or trachytes.

Dolerites.

Those rocks of the Goemaigebergte which typically have an ophitic structure are divided by Dr. Emil Gutzwiller into two groups, the diabase-porphyrites and the diabases; the former group containing no olivine or diallage, while the second group usually contain one or other of them.

Very few specimens of dolerite of the period of the Pahang Volcanic Series have been collected in Pahang, so a detailed comparison

[1] E. E. L. Dixon, Quart. Journ. Geol. Soc., vol. lxvii, pp. 511–31, 1911.

of the specimens in the two countries would be without value, but one difference is sufficiently clear, namely that the felspar of the Pahang Volcanic Series dolerites is very much more acid in character, varying, in the five or six specimens examined, from oligoclase with an extinction angle of 12° to andesine. As already mentioned in the detailed description of the Pahang Volcanic Series dolerites, one of them contains quartz which is probably original. The alteration of the augite in both series results either in the formation of chlorite or of an amphibole. None of the dolerites collected from the Pahang Volcanic Series contain either diallage or olivine.

Andesites.

Dr. Emil Gutzwiller follows the custom of the Continental petrologists in using the name *porphyrite* for the older andesitic lavas.

Judging by the descriptions of the ten Goemaigebergte porphyrites given in *Mijnwezen*, 1912, the most obvious difference is in colour, for none of the porphyrites of South Sumatra have the red-brown colour which is so typical of many of the Pahang Volcanic Series andesites. A more important difference is in the composition of the felspar, for only two specimens out of the ten contain oligoclase-andesine, the remainder having felspars varying from andesine-labradorite (three specimens), through labradorite (two specimens), to bytownite (two specimens) and anorthite (one specimen), whereas the felspar of the Pahang Volcanic Series andesites on the other hand is never more basic than andesine.

The mode of alteration of the felspars in both the Pahang Volcanic Series and the Sumatran andesites is occasionally the same, then resulting in both cases in the formation of chlorite, but usually there is a considerable difference in the products of alteration of the two series, which is to be expected after considering that, apart from occasional specimens, the composition of the felspars in the two series is so widely different. In many of the Pahang Volcanic Series rocks the alteration product is a brown, opaque, extremely fine-grained material, which is probably kaolin, often associated with tiny flakes of secondary mica, not a common mode of alteration for the felspar of the Sumatran rocks. On the other hand, the felspar of the Sumatran rocks is often altered with the separation of epidote and calcite (saussurite). The oligoclase-andesine felspar of one of the Tembeling andesites contains a good deal of epidote, but in most of the Pahang Volcanic Series rocks the epidote which they contain has not been formed from the felspar. These rocks usually contain calcite, sometimes formed by alteration of the felspar, but often simply added to the rock by infiltration from neighbouring calcareous sediments.

The porphyrites of South Sumatra are divided petrologically into two groups, the labradorite-porphyrites and the augite-porphyrites, the first group containing no phenocrysts of pyroxene, but in some cases (Nos. 7, 8, and 9 Gloegoer) chlorite aggregates occur which are undoubtedly secondary after amphibole or pyroxene. In some of these, augite grains occur unaltered in the groundmass. A similar

division of the Pahang Volcanic Series andesites into those with and those without augite could be made, but, as already mentioned, it is quite possible that all the andesites originally contained augite, which in some cases has been weathered to chlorite. The shape of the chlorite aggregates in some of the lavas confirms this idea, but in others chlorite occurs only as irregular areas in the groundmass, and there is no confirmatory evidence as to its origin.

Titanite is an alteration product common in the Sumatran rocks, whereas it was seen in only one of andesites of Pahang; some of the Sumatran augite-porphyrites are uralitized, and titanite occurs as a secondary product formed during this change. Another point of difference is that some of the Pahang Volcanic Series andesites contain olivine, whereas none occurs in the Sumatran porphyrites.

Apart from the differences mentioned above, the andesites of the two series bear a certain resemblance one to the other. Both are practically always holocrystalline with plagioclase felspar making up the greater part of the rocks as phenocrysts and groundmass, the latter containing little or no glassy base. Apatite is widespread in small quantities in all the Pahang Volcanic Series and Sumatran andesites, and a colourless augite with its alteration products are also widely distributed. Rhombic pyroxene is always absent.

Serpentine.

Serpentine and peridotites are found in many of the islands of the Dutch East Indies, including Java, Borneo, the Moluccas, and the west coast of Sumatra. Dr. Verbeek writes a description of all these occurrences in *Mijnwezen, Wetenschappelijk gedeelte*, 1905, and from this it appears that the serpentine in all these places was derived from olivine. Most of the serpentine outcrops in the Peninsula show no traces of the original rock, but occasionally, as in Negri Sembilan, remnants of amphibole suggest that the serpentine owes its origin to that mineral. An outcrop in the Perak River, however, resembles serpentine of the islands of the Archipelago in containing remnants of olivine.

Tuffs and Breccias.

They differ in much the same way as do the Sumatran lavas from the Pahang Volcanic Series lavas. The andesitic constituents are similar, except in the composition of the felspars, but no simultaneous effusion of rhyolite material took place in Sumatra, and so the Sumatran fragmental rocks differ from those of Malaya in that the tuffs are of an unmixed andesitic composition. The same difference applies to the breccias of the two areas. There is nothing similar to the remarkable deposits of boulders in tuff in the Sumatran area.

The age of the Sumatran volcanic rocks is given by Verbeek[1] as youngest Palæozoic, while Volz[2] gives them a pre-Triassic

[1] R. D. M. Verbeek, "Top. En. geol. beschrijving van een gedeelte van Sumatra's West Kust": Batavia Landsdrukkerij, 1883, p. 270.

[2] W. Volz, "Zur Geologie von Sumatra": Geol. und paläontol. Abhandlungen herausgegeben von E. Koken, Neue Folge, Bd. vi, Hft. ii, pp. 87 ff., Jena, 1904.

age, and on account of this Dr. Aug. Tobler, in his description of the volcanic rocks of South Sumatra in *Mijnwezen*, 1912, assigns them to the Permo-Carboniferous period. Thus, in age the Sumatran and Malayan volcanic rocks correspond, for the latter are extensively interstratified with Raub rocks, and certain fossils from limestone beds belonging to the Raub Series give it a Permo-Carboniferous age.

Volz says that the volcanic rocks of South Sumatra do not persist so late as the Triassic period, and this is a point of difference from the Malayan rocks, for the latter were being deposited during and probably later than the period of formation of the Lower Gondwana beds of Pahang, which are correlated with the uppermost Trias.

The Tertiary volcanic rocks of the Goemaigebergte seem, from Dr. Gutzwiller's descriptions, to contain no epidote, and this agrees with the rocks of the Malay Peninsula, where rocks younger than the Mesozoic granite contain no epidote. It will be remembered that some specimens of the dark-purple quartz-porphyry of Selangor contain epidote, and that this is taken as evidence of the pre-Granitic age of the intrusion.

Conclusions.

It is not possible to define the limits of the volcanic period with any certainty. The majority of the tuffs and lavas are interstratified with Raub shales, and fossil evidence proves that some of them are of Permian age. The field evidence suggests that the Raub shales are contemporaneous with the Raub limestones, and the latter contain fossils of Upper Carboniferous Limestone (*Visean* age), but no volcanic rocks have yet been seen that were underlain and overlain by Raub limestones. A boulder-in-tuff deposit was seen in contact with a vertical face of limestone in the river bank a few hundred yards down-stream from Lubok Plang, but according to the theory that the boulders are a beach-deposit it is certain that the deposit is lying unconformably against the limestone. So we have proof that there was volcanic activity during the Permian period (late Raub), and there is no proof that it started so early as the Carboniferous period.

It is possible that volcanic activity continued during the period of dry land which prevailed through the greater part of the Triassic and perhaps during a part of the Permian period, and we know that tuffs were being deposited at the coming on of the Gondwana shallow-water conditions, when the beach-deposit was formed.

Tuffs and lavas were extruded during the deposition of the earliest Gondwana rocks in the north and south zone now marked by the Pahang and Tembeling Rivers and probably also further to the east, though this last point has not been investigated. No cases of Pahang Volcanic Series intrusions penetrating Gondwana rocks have been noticed, though there are several doubtful cases; for instance, the granophyre north of Pulau Guai and the quartz-porphyry at Jeram Gading*. However, if the beach-deposit of boulders in tuff was formed immediately before the earliest Gondwana rocks of the locality it is clear that the granophyre was intruded and laid bare before this date, for granophyre boulders are included in the deposit.

Rhyolite-lavas were extruded during the Raub period, and apparently eruptions of acid rocks and andesites occurred alternately. There is no evidence that rhyolites were extruded as lavas later than the Raub period, but eruptions of andesitic composition took place during the formation of both the Raub and Gondwana rocks, and as the eruptions were in full activity during the formation of the earliest Gondwana beds it is possible that they persisted through the period of dry land.

All the Raub volcanic rocks that have been examined were evidently deposited under the sea, and such was the case too with the Gondwana volcanic rocks, though in the latter case it is quite probable that for some time the volcanic vents continued to be above sea-level. Radiolarian cherts are associated with Pahang Volcanic Series rocks at Lubok Plang and on the Main Range in Lower Selangor*, and it is possible that the silica in the sea-water necessary for the building up of Radiolarian tests was supplied by pneumatolytic emanations from these eruptions. However, no proof of extensive albitization of the Pahang Volcanic Series rocks is available, and this is a serious drawback to the theory that the two rocks are related in origin.

The only intrusion of dolerite that was seen on the Pahang Railway was in a weathered railway cutting near the boundary of Gondwanas and Raubs, and it was uncertain whether or not it penetrated Gondwana rocks. There is no proof whether the dolerite is of Raub or Gondwana age. The absence of dolerite boulders from the beach-deposit can be explained by the scarcity of the dolerite outcrops, and does not prove anything about the age of the intrusions.

NOTICES OF MEMOIRS.

I.—Swiney Lectures on Geology.[1]

A course of twelve lectures[2] on "The Mineral Resources of the British Empire" will be delivered by Dr. John S. Flett, F.R.S., at the Royal Society of Arts, 18 and 19 John Street, Adelphi, W.C.

Syllabus.

Lecture I. Tuesday, November 13. Introductory.—The mineral industries in peace and war. Relation of mineral production to Colonial development. Distribution of minerals of economic value in the British Empire. Trade between Britain and Colonies in minerals, metals, etc., in normal times. Effect of war on mineral production and distribution in the Empire. Statistics of British Imperial production. Resources of the Empire in minerals.

[1] With the sanction of the Trustees of the British Museum (Natural History).

[2] The lectures will be given on Tuesdays, Thursdays, and Fridays at 5.30 p.m., beginning Tuesday, November 13, and ending Friday, December 7, 1917. To be illustrated by lantern slides. Admission free.

II. Thursday, November 15. GOLD.—World's production of gold at different dates. History of gold-mining in Great Britain. Gold-mining in early times in India, Africa, etc. Discovery of gold in Australia: history and present condition of gold-mining in Australian States. South African goldfields: Transvaal, Rhodesia, etc. Gold-mining in India, Canada, British Guiana, New Zealand, etc.

III. Friday, November 16. SILVER, PLATINUM.—Sources of silver and nature of silver ores. Extraction of silver from lead ores. Silver production of Great Britain. Canadian silver-mines and the history of their development. Australasian silver-mines, especially Broken Hill. Platinum deposits of British Columbia.

IV. Tuesday, November 20. IRON.—Occurrence of iron ores and their origin. Production of iron in Britain and the Empire. Iron-ore deposits of Great Britain. British imports of iron ore and their sources. Iron-ore deposits of Canada and of the Australian States. Iron-ore deposits of South Africa.

V. Thursday, November 22. COAL.—Origin of coal and nature of the different varieties. Properties and utilization of coal. Coal-production of the Empire. Exports and imports of coal. British coal-fields and their resources.

VI. Friday, November 23. COAL (*continued*).—Coal-fields of Canada: their production and reserves. Coal-fields of India. Coal-fields of South Africa, Rhodesia, Nigeria. The coal deposits of the Australian States.

VII. Tuesday, November 27. OIL.—Sources of mineral oil: their method of origin and mode of occurrence. History of oil industry and world's production of oil. Oil shales of Scotland, Australia, and Canada: their treatment and their products.

VIII. Thursday, November 29. OIL (*continued*).—Oil and pitch in Trinidad. Oil and gas wells of Canada. Oil-fields of Egypt, Burmah, New Zealand, Persia. History of mineral oil and geology of the oil-fields.

IX. Friday, November 30. SALT, PHOSPHATES, SULPHUR, ETC.—Deposits of rock salt in Britain, Canada, India, etc. Mineral phosphates in British possessions. Sulphur and pyrites: their distribution and uses. Asbestos mines of Canada, Africa, etc. Graphite of Ceylon. Nickel and cobalt in Canada.

X. Tuesday, December 4. COPPER, TIN, TUNGSTEN, ETC.—Copper and tin mining in Britain. Copper production in Canada, Africa, New Zealand. Tin-mining in the Malay States. Tungsten: the sources of supply in the British Empire. Molybdenum.

XI. Thursday, December 6. LEAD, ZINC, MANGANESE, ETC.—British lead-mining, past and present. Sources of lead and zinc for British industries. Zinc-lead ores of Australasia. Canadian lead and zinc deposits. Manganese ores of India. Antimony.

XII. Friday, December 7. DIAMONDS AND OTHER PRECIOUS STONES.—Indian diamond production. The diamond fields of South Africa and South-West Africa: their geology and history. Australian diamonds. British Guiana. The Burman ruby deposits. Precious stones of Ceylon. Queensland opals and sapphires.

II.—A Paleocene Bat. By W. D. Matthew. Bull. Amer. Mus. Nat. Hist., vol. xxxvii, pp. 569–71, September, 1917.

BATS with well-developed wings are already known from the Upper Eocene of Europe. A highly specialized skull of a bat has now been found in the still older Basal Eocene (Wasatch formation) of Colorado, U.S.A. According to Dr. Matthew, this specimen represents a new genus and species of the family Phyllostomatidæ, which still exists in tropical America. It has an unusually slender snout and a comparatively small canine tooth.

III.—Huesos anormales de Llama y de Condor. By Cayetano Martinoli. Physis (Buenos Aires), vol. iii, pp. 69–74, 1917.

PALÆONTOLOGISTS have long been interested in rare cases of three-toed horses, which recall the condition of the foot in the Miocene and Pliocene Equidæ. Martinoli now describes and figures an analogous case of polydactyly in a llama (*Auchenia lama*). As shown by his figure, the abnormal metacarpus consists of four well-defined bones fused together, and all probably bore phalanges.

IV.—The Albertella Fauna located in the Middle Cambrian of British Columbia and Alberta. By Lancaster D. Burling. *American Journ. Science*, vol. xlii, pp. 469–72, 1916.

THE Albertella fauna has hitherto been regarded as Lower Cambrian, but certain new facts of stratigraphy are mentioned in this paper to prove its Middle Cambrian age. Text-figures are given of *Albertella bosworthi*, Walcott (British Columbia), and *A. helena*, Walcott (Montana and British Columbia).

REVIEWS.

I.—Fossil Plants; a Text-book for Students of Botany and Geology. By A. C. Seward, M.A., F.R.S. Vol. III: Pteridospermæ, Cycadofilices, Cordaitales, Cycadophyta. 8vo; pp. xviii, 656, with frontispiece and 253 text-figures. Cambridge University Press, 1917. Price 18*s*. net.

PROFESSOR SEWARD'S book is a continuation of his systematic account of fossil plants, taken up from the end of vol. ii, which appeared in 1910. The author was so rash as to make certain statements in his preface to the previous volume as to the scope and time of appearance of the remaining portion of his work. Hence the explanation in the preface of vol. iii that the promised account of the geographical distribution of plants at different stages in the history of the earth has been crowded out of vol. iii and the following vol. iv, now in the press, and must therefore form the subject of a separate book. This is all to the good from the students' point of view; the subject of geographical distribution in time, if treated in the full and careful manner which we expect from Professor Seward, may well form a separate volume. We trust that the leisure which one associates with the mastership of a college in an ancient

university may allow of its speedy completion. Like the growing point of a Monocotyledon, the scope of Professor Seward's undertaking has broadened with its growth, and the completed work will form a landmark in the literature of palæobotany.

The present volume opens with a general account of recent Cycads, the headline to which contains a curious misprint, one of the very few we have noticed in the volume, the general production of which is excellent, with clear and well-arranged text. The account of the Pteridosperms was begun in vol. ii, but the treatment of the better-known genera was reserved for the present volume; "as these genera are founded to a large extent on anatomical characters oscillating in their essential features between recent Ferns and Cycads," this intercalation of a chapter on recent Cycads was a happy thought. In the second chapter the author resumes his descriptive account of the Pteridosperms. These are considered under the headings Lyginopterideæ and Medulloseæ. Under the former is a full description of *Lyginopteris* (a name which on principles of nomenclature replaces the somewhat better-known *Lyginodendron*), including vegetative and reproductive organs, with the seed which was formerly known as *Lagenostoma*. The subject of nomenclature is a difficult one for the writer of a textbook on palæobotany. Having pieced together the fragments which have been described under different names at different times, he has to decide what name the more or less perfect entity shall bear; and it must sometimes happen that a better-known name must give place to one which is for the moment less well known. Professor Seward is wise to be guided by definite principles; in a book like the one before us, which will be a standard textbook for some time, he has the opportunity of fixing a name for the use of students.

In this chapter the author discusses the use of the term "seed" for the structure represented by *Lagenostoma* and other Palæozoic seeds. The difficulty is the absence of an embryo, a very important feature, the development of the embryo being the outward and visible sign of the process of fertilization. The opinion is expressed that this negative character should not be allowed to outweigh the evidence furnished by morphological features as to the applicability of the term seed (p. 61). Later (p. 301) the writer refers to "the promotion of the megasporangium and megaspore of the Pteridophyta to the higher stage represented by the integumented megasporangium (nucellus) and single megaspore that in the main fulfil the definition of a seed". How, then, shall we define an ovule? The seed of the modern phanerogam or seed-plant is so characteristic and morphologically well-defined a structure that one somewhat regrets the application of the same term to these early attempts to achieve the same biological function. Professor Seward is not, we think, quite sure of his position, as on each occasion he leans on the stalwart arm of Professor Oliver. As Professor Oliver says, "there is a long chapter in evolution to be deciphered before we can connect . . . the seed of *Lyginodendron* with the sporangium of any fern at present known to us." We might add, there is a long long trail between *Lyginodendron* and the modern seed-bearing plant.

The account of *Heterangium* and the associated seed *Sphærostoma* follows that of *Lyginopteris*, after which is a chapter on Medulloseæ and the *Trigonocarpus* seed-type. The Lyginopterideæ and Medulloseæ are regarded as offshoots of a common stock, the latter occupying a position farther removed from the filicinean ancestry than the former.

Under the heading Cycadofilices is a description of several types represented by stems, but which in the absence of definite information with regard to the reproductive organs cannot be assigned to the Pteridosperms, including among others *Megaloxylon*, *Cycadoxylon*, *Calamopitys*, *Cladoxylon*, and *Protopitys*; their structure is well illustrated by photographic reproductions of sections and diagrammatic figures.

The two following chapters are devoted to the Cordaitales under the headings Poroxyleæ, comprising *Poroxylon*, Cordaiteæ, including *Cordaites* proper with some allied or imperfectly known genera, and Pityeæ, including the large petrified stems known as *Pitys* and other genera founded on stems of comparable structure. A chapter on Palæozoic gymnospermous seeds forms a useful comparative study of selected examples illustrating the remarkable variety in details of external form and internal structure associated with certain fundamental features which they have in common. Here, again, the illustrations are most helpful.

The concluding chapters deal with the fossil Cycadophyta. These are represented by the important class Bennettitales and include *Cycadeoidea* (more generally known as *Bennettites*), *Williamsonia*, the recently described *Williamsoniella*, and other less perfectly known genera; these forms are fully and carefully described. A chapter follows dealing (1) with Cycadean stems other than *Cycadeoidea*, the best known of which are those assigned to *Bucklandia*, and (2) with reproductive organs of fossil Cycadean plants which cannot be assigned to Bennettitales. Some of these, which have been described by various authors as *Carpolithus*, agree in external features with the seeds of modern Cycads, but in the absence of anatomical details their position must remain doubtful.

The last chapter, Cycadophytan fronds, contains a description of a number of genera founded on detached leaves which are believed to be Cycadean.

A list of works referred to in the text (including vols. iii and iv), arranged alphabetically under the author's name, occupies nearly fifty pages.

A. B. Rendle.

II.—Cambridge County Handbooks.

Bedfordshire. By C. Gore Chambers. Cambridge County Handbooks. pp. x+195. Cambridge University Press. 1917.

Although Bedfordshire is one of the smallest of the English counties, nevertheless it shows a surprising diversity of natural features and productions. This diversity is closely correlated with the geological structure of the district. From this point of view the county may be divided into three sections; firstly, the Jurassic clays

of the north, which form low, gently rolling, or flat ground, mainly occupied by the valley of the Ouse; secondly, the conspicuous ridge of the Lower Greensand, with its pine-woods and heather, extending across the county from Leighton Buzzard to Potton and Sandy; and, thirdly, the Chalk downs of Luton and Dunstable, which rise at Kensworth Hill to a height of some 800 feet, and afford an excellent example of the Down type of scenery. Some of the superficial deposits of Bedfordshire are also of considerable interest, notably the gravels of Biddenham, which have long been classical in the study of Palæolithic man in Britain. It was here that the results obtained by Boucher de Perthes on the Somme were first established and extended for Britain. This discovery formed a notable landmark in the history of prehistoric archæology.

In this small book Mr. Gore Chambers has given a concise and well-arranged account of the natural features and products, archæology, and history of Bedfordshire, showing clearly how the development of population, communications, and industries is closely dependent on the geography and geology of the district. Although not containing within its borders any places of paramount importance, Bedfordshire was even in very early days an important centre on lines of communication, since the Icknield Way and the Watling Street crossed at Dunstable. These great roads are no doubt very ancient, probably going back to Neolithic times. Again, the Stane Street, an important road from London to the North, skirted the eastern side of the county, while the town of Bedford was an important stronghold at an early date.

The mineral wealth of the county is not great; the coprolite industry and the quarrying of the Totternhoe Stone for building purposes are now almost or quite extinct, but the sands of the Lower Greensand have been largely used for glass-making and other commercial purposes; this is an industry that is likely to increase in the future. Near Leighton Buzzard there are beds of pure white sand of very good quality for glass. The yellow iron-stained sands of Sandy and other districts are chiefly used for building, iron-moulding, and filter-beds. Bedfordshire is on the whole an agricultural county, and the experimental work carried on at Woburn is world-famous. The alluvial soils of the Ivel Valley are specially suitable for market gardening, and of late years an enormous trade has sprung up in garden produce for the London market, ordinary garden vegetables being here grown by hundreds and thousands of acres. It is clear, therefore, that the industrial prosperity of Bedfordshire is largely founded on a geological basis.

R. H. Rastall.

III.—Persistence of Vents at Stromboli and its bearing on Volcanic Mechanism. By H. S. Washington. Bull. Geol. Soc. America, vol. xxviii, pp. 249–78, pls. vi–ix.

In this paper the author has brought forward the evidence of the constancy of position of the vents on the crater terrace of Stromboli. By a careful comparison of old plans and sketches, going back as far as 1776, he has established the fact that certainly three,

and probably more, of these vents have not altered their positions to any appreciable extent since that date. He compares with this the constant position of the lava lake, Halemaumau, in the crater of Kilauea, and suggests that there is some evidence for a similar constancy at Vesuvius and Etna, though here the information is much less definite.

From these facts the author draws the following conclusions: (1) The vents are the openings of conduits which have pierced through the solid rock for the greater part of their courses. (2) The lengths of these conduits must be considerable, for, if this were not so, we should expect vents to break through the thin crust at various places at different times. (3) The persistence and relatively small size of the vents, which must be wider than the conduit, indicate that there has been very little corrosion of the vent by the uprising magma, which is presumably kept fluid at a lower temperature than the melting-point of the surrounding walls, owing to its dissolved gases. (4) The complete absence of synchronism in the activity of the different vents shows that they communicate individually with the magma reservoir. (5) Judging by the size of the vents the conduits cannot be more than "a few tens of metres" wide.

These conclusions, together with the fact that the vents occur at the top of a scarp more than 2,000 feet high (probably caused by the subsidence of the north-west portion of the original crater), lead the author to adopt Daly's "gas-fluxing" hypothesis to explain their formation. This hypothesis is briefly described as follows: Gas bubbles rise to the top of the magma in the reservoir and accumulate in irregularities ("cupolas") in the roof. These gases are supposed to be at a higher temperature than the magma owing to their exothemic interactions and so "blowpipe" their way up through the overlying rock. The action of these gases will only extend over a small area, so that many narrow independent pipes will be formed. This hypothesis is especially applicable to the formation of the vents on the Stromboli crater terrace, if this has been formed by the sinking of a large mass to the north-west, since the magma reservoir may be assumed to have maintained its original level under the remaining centre part of the original mountain, which would then be the most favourable place for the "gas-fluxing" action to take place.

The paper is illustrated by some very interesting photographs, sketches, and reproductions of illustrations from the old books dealing with the volcano.

W. H. W.

IV.—The Eruption of Sakura-jima on January 12, 1914. By Charles Davison, Sc.D., F.G.S. *Science Progress*, No. 45, July, 1917, pp. 97–110.

In *Science Progress* for July, 1917, Dr. Davison gives a very interesting summary of Professor Omori's investigations[1] into the eruption of Sakura-jima which took place in January and

[1] "The Sakura-jima Eruptions and Earthquakes": Bulletin of the Imperial Earthquake Investigation Committee (Tokyo), vol. viii, pp. 1–34 (1914), 36–179, 181–321 (1916).

February, 1914. Sakura-jima is an island, one of a series of five volcanoes situated along a N.N.E.–S.S.W. line on or near the southern end of the island of Kyushu, which is the most southerly of the main islands of the Japanese Empire. The activity of the Japanese volcanoes is restricted to certain periods, separated by more or less long periods of quiescence; and in this present active period 194 eruptions occurred from eleven volcanoes between 1909 and 1914. The eruption was preceded by the usual premonitory warnings, the significance of which was so completely understood by the authorities that the whole population of the island, some 23,000 in number, were removed with the loss of only three lives. The paroxysmal phase was one of extraordinary violence; it began with the ejection of stones and ashes from one of the main craters, which was followed somewhat later by the outpouring of lava from two groups of craterlets on the west and south-east sides of the island; it was also accompanied by a severe earthquake, which was recorded by European observatories, and by a small earthquake wave, which was probably caused by the subsidence of the bottom of the neighbouring Kagoshima Bay.

Detailed surveys of the district, before and after the eruption, show considerable elevation (between 30 and 40 feet) of the mass of the island itself and subsidence of from 4 to 20 inches over the surrounding country. These displacements require the sinking of a mass of the crust of at least half the volume of the material ejected during the eruption. The sound phenomena were found to behave in a normal manner, that is to say that there were two zones, one near and one far from the volcano, in which the sounds were separated by a silent zone, the middle line of which lay about 75 miles from the mountain. The chief eruption of Sakura-jima was associated with eruptions from the other vents in the line. Three out of four of these were active between January 8 and March 21, beginning with the most northerly and ending with the most southerly.

W. H. W.

V.—The Colour of Amethyst, Rose, and Blue Varieties of Quartz. By T. L. Watson and R. E. Beard. Proceedings of the United States National Museum, Washington, 1917, pp. 553–63.

Up to the present time but little information is available as to the cause of the disperse colours of minerals, as distinguished from the colours due to the actual chemical constituents of the mineral itself. The authors of this paper have made a careful investigation of the chemical composition and physical structure of variously coloured varieties of quartz with a view to discovering the reason of the wide variations that exist in different types. The principal constituents found which might give rise to colour are manganese, titanium and iron, with traces of cobalt. On the average of thirteen analyses it was found that amethyst contains the highest percentage of manganese, while rose quartz has the highest percentage of

titanium; the quantities are, however, very small, ranging from ·0005 to ·0031 per cent, while iron does not exceed ·006 per cent. The authors believe that the colour of amethyst is mainly due to manganese, which probably exists in the form of colloidal particles of ultramicroscopic size, consisting of manganese oxide. Since the colour of rose quartz when destroyed by heat cannot be restored by daylight or by exposure to radium, it is considered not to be due to any inorganic substance.

The cause of the peculiar blue colour of quartz from Virginia was also investigated. This is found in a highly titaniferous petrographical province, and the colour is believed to be in the main an interference phenomenon due to the scattering of light by minute prisms of rutile arranged with crystallographic regularity. This is similar to the explanation of the blue colour of the quartz of the Charnockite series, as given by Holland. Heating does not destroy the blue colour, while purple and rose-coloured varieties are completely decolourized by heating to about 1100° C. for ten minutes.

This investigation is an interesting and suggestive piece of work, which is well worthy of imitation on other minerals whose colour is due to minute quantities of some foreign substance. By way of criticism it may perhaps be suggested that the authors have scarcely paid sufficient attention to the possible influence of the iron oxides present in determining the colour of these varieties of quartz.

R. H. Rastall.

VI.—The Magnesite Deposits of Grenville District, Argenteuil County, Quebec. By M. E. Wilson, Geological Survey of Canada. Ottawa, 1917.

In recent times magnesite has become increasingly important as a refractory mineral for metallurgical purposes, and during the last three years a demand has sprung up in America for a supply from home sources, most of the material used having been formerly imported from Austria and Greece. This has led to the development of a considerable industry in Quebec. The magnesite is found in the rocks of the Grenville Series, the oldest subdivision of the Pre-Cambrian of the district. These were originally sediments consisting of sandstone, shale, and limestone, which have undergone an intense degree of metamorphism; the limestones have been converted into crystalline marbles, partly dolomitic, while some varieties contain a proportion of magnesium carbonate in excess of that required to form dolomite; some samples show as little as 7 per cent of lime. From the descriptions given in this memoir it appears that the enrichment in magnesia may be due in part at any rate to intrusion of masses of pyroxenite and other basic rocks rich in magnesia connected with the Buckingham Series. The process may have been effected largely by the aid of pneumatolytic solutions arising from basic or ultrabasic magmas. The magnesite is largely associated with serpentine and diopside rocks, and the whole has been crushed by dynamic metamorphism into lenticular masses of varying size and composition. Petrographically the rocks are of great interest: the

minerals present include many of those characteristic of areas of dedolomitization by igneous intrusions. The total amount of magnesite now in sight is estimated at about 1,000,000 tons, and there may be a good deal more under certain drift-covered areas.

R. H. R.

VII.—A Review of Mining Operations in the State of South Australia during the half-year ended June 30, 1916. Compiled by Lionel C. E. Gee and issued under the authority of the Honourable the Minister of Mines. Adelaide, 1916.

THIS report deals with the mineral production of South Australia during the above-mentioned half-year, the minerals with which it is concerned being mainly copper, gold, salt, and some silver lead. The search for copper has been stimulated by war demands, and gold returns are recorded as improving. Logs and detailed sections of a number of deep bores which were put down in search for copper are given. Unfortunately these were not successful in striking any valuable copper deposits. The rocks passed through were mainly quartzite, mica-schist, and gneiss.

Interesting accounts are given of the prospecting for tungsten minerals at Callawonga Creek and of a survey of the hundred of Kongorong, which was carried out to determine the advisability of boring for petroleum. At Callawonga Creek valuable deposits of ferberite are found, in conjunction with tourmaline, in veins which are intermediate in character between pegmatite and quartz veins. The distribution of the mineral is irregular and in some places it is associated with finely divided gold. Work has been carried out to a considerable extent on the surface and the field seems suitable for deeper work.

The survey of the hundred of Kongorong is a striking example of the advantage of calling in reliable expert advice before undertaking any enterprise. Petroleum seepages were reported from this district, which rested on the evidence of a specimen of asphaltic bitumen, which was said to have been discovered there. It was also alleged that the structure of the country as shown by the "ranges" was suitable for the accumulation of petroleum deposits. The Government geologist found, on surveying the district, that the "ranges" were nothing more than parallel lines of dunes formed during the gradual elevation of the coast, and that the only solid rock which could be detected, over most of the area, was a polyzoal limestone, which was proved by boring to rest on sands and clays with lignite. These were apparently fairly horizontal, and no clue as to the real structure of the district could be obtained. Moreover, no traces of petroleum were found, and it is supposed that the facts of the discovery of the bitumen were not strictly accurate. The result of this investigation was that no work was undertaken, and money saved which would otherwise have been thrown away on a useless enterprise.

The review is illustrated by photographs of the mining operations and of the Kongorong dunes.

W. H. W.

VIII.—The Wolfram Mines of Bamford and Carbine Hill, North Queensland. By L. C. Ball, B.E., Assistant Government Geologist. Geological Survey of Queensland, Publications No. 248 and 251.

THESE two small mining fields in the North of Queensland produce mainly wolfram, though they also contain a certain amount of molybdenite and tinstone and at Bamford bismuthite. The latter field has been in operation since 1893 and has produced in addition to other minerals about 1,580 tons of wolfram concentrates, while the Mount Carbine field produced about 670 tons between 1906 and 1912. The production of both fields was, at the time of writing, on the down grade, since the rich surface ("Shoad") deposits were exhausted and the deep veins had not been fully exploited owing to lack of capital and difficulty of working.

The ore in both cases occurs in veins associated with granites. At Mount Carbine, where the country rock is mainly slate, the mineral veins are found in the slates; while at Bamford, where the granite is intrusive into massive porphyry, the veins are generally situated in the granite itself, near the contact zone, and are accompanied by greisenization and the formation of quartz rock. At Bamford the veins often widen out into "vugs" or broad cavities filled with quartz, which is the chief "gangue", and metalliferous minerals. Following the ideas of Daly and Van Hise and also the experiments of Fouqué and Michel Levy, the author puts forward the hypothesis that the silica was originally introduced into the veins in the colloid state. In this condition it would allow the free passage of the mineralizing gases, but, as the jelly became viscous, the gases would be trapped and attack the side walls of the veins, forming "vugs". Finally the silica was probably precipitated in the crystalline form owing to the action of tungstic acid, since this has been shown to exercise a similar action on albumin.

The author describes the mining properties in detail and also the methods of dealing with the ore, the supplies of water, timber, and other necessaries of mining communities. The memoirs are illustrated by photographs of the scenery and the mines, and also by diagrams of the most interesting vein phenomena.

W. H. W.

IX.—The Satsop Formation of Oregon and Washington. By J. Harlen Bretz. *Journal of Geology*, vol. xxv, 1917, pp. 446–58.

THE Satsop formation is the name given to a series of deposits composed of sands and gravels with occasional beds of clay and lignite, which is found in the valleys of the rivers of Washington and Oregon. It occurs along the coast, in the valleys of Coast Range, in the valley between the Coast Range and the Cascade Range, and in the gorge cut through the Cascade Range by the Columbia River. It rises from sea-level, or below, on the coast to the height of 3,000 feet in the Cascade Range, and belongs to the cycle of denudation previous to that now in operation. It was evidently deposited after the uplift of the Coast Range, as it forms terraces

along the valleys cut across this range and also terminates abruptly against its eastern slope. But in the gorge of the Columbia River which is cut through the Cascade Range it rises above the river-level, as it is followed eastwards to the centre of the range, where it begins to fall, and is found on the eastern side to be again at or near river-level. It here contains a lava-flow, and is at one place covered by another. It rests unconformably on the denuded edges of some of the earlier anticlines.

From this it is seen that the Satsop formation is later than some of the folding of the range, but earlier than the final uplift. The Cascade Range has been shown by Russell and others to be an uplifted, dissected peneplain, which has been called the Methow peneplain, and the author correlates this with the surface on which the Satsop formation rests.

By the fossil content of the clays and lignites which it contains it is shown to be of late Pliocene or possibly Pleistocene age. This determination would show that the final uplift of the Cascade Range took place either in very late Pliocene or Pleistocene times.

W. H. W.

REPORTS AND PROCEEDINGS.

Edinburgh Geological Society.

Dr. Flett, President, in the Chair.

The following paper was read on March 21, 1917 (Abstract received October 12, 1917): "Geology of Kinkell Ness, Fifeshire" (with lantern illustrations). By D. Balsillie, B.Sc., F.G.S.

The largest, best exposed, and most interesting volcanic vent along the northern shores of Fife is that which has been laid bare at the headland of Kinkell Ness, and a portion of the enclosed material of which has been sculptured into the picturesque shore stack known as the Rock and Spindle. The margins of the vent were first referred to by the author, these being easily traceable, he said, except on the southern and western sides where the fragmental accumulations of the neck pass into the grass-covered cliff line above high-water mark. Thereafter the character and arrangement of the materials filling the old volcano were described in some detail, special attention being called to the occurrence in the agglomerate of numerous blocks of a white coral-bearing limestone that probably belongs to the base of the Carboniferous Limestone Series—this being a higher stratigraphical horizon than any of the rocks now surrounding the vent.

Though, as emphasized by Sir Archibald Geikie, there is no evidence to show that lava streams were ever emitted at this volcanic centre, the uprise of igneous material in the chimney is impressively demonstrated by the masses, dykes, and veins of igneous rock that ramify through the ash. Some of these intrusions have caught up such a quantity of extraneous fragments that their simulation of true agglomerates is very striking and apt to be exceedingly misleading.

The petrographic characters of the basalts are not easy to ascertain on account of their altered state. Drs. Flett and Campbell are

agreed that, although nepheline cannot possibly be determined in any of the author's micro-sections, yet the general resemblance of the latter to those of the felspathoid-bearing basalts of the St. Monans and Elie district is so remarkably close as probably to place beyond question their related origin.

When discussing the geological age of the Rock and Spindle vent, the author said he was inclined until recently to concur with Sir A. Geikie in placing it along with other East Fife necks in Permian or, at all events, in post-Carboniferous time. Revision of this opinion would, however, now appear necessary. A careful examination of the Spindle basalt reveals the exceptionally interesting fact that there are enclosed in it, apparently directly, numerous fish teeth in a condition of excellent preservation. Dr. Peach believes he has identified *Megalichthys* and *Psammodus* in the specimens collected. Should these fossils, on fuller investigation, prove not to be derived, then the vent must be carried back in age to the period of the Carboniferous Limestone.

CORRESPONDENCE.

SALT-WEATHERING AND SUPPOSED WORM-BORINGS IN AUSTRALIA.

Sir,—The interesting notice, signed W. H. W., of Mr. E. J. Dunn's "Geological Notes, Northern Territory, Australia" (Geol. Mag., March, 1917, p. 134), led me to communicate with Mr. Dunn, who has kindly sent me copies of his recent papers, on which I venture to offer the following remarks.

The appearance of contortion observed on the surface of a two-inch core in presumed Carboniferous rocks, and interpreted by Dr. Jensen and Mr. Dunn himself as due to the borings of worms, reminds one rather of some pieces of the Cotham Stone or Landscape Marble (see Horace B. Woodward, Geol. Mag., March, 1892, p. 110). The rock before its disturbance appears to have consisted of thin layers of sand alternating with thin layers of black shale. The latter, being carbonaceous, may well have contained in places a considerable amount of decaying organic matter. Consequently the explanation of these disturbances may be the same as that put forward by Mr. Beeby Thomson for the Cotham Marble (August, 1894, Quart. Journ. Geol. Soc., vol. l, pp. 393–410). That is to say, bubbles of gas springing from the decomposing carbonaceous matter pass through the overlying laminæ and throw them into confusion. When the streams of bubbles are concentrated in definite places naturally a tubular form is assumed; hence the resemblance to worm-borings.

Here one may recall the somewhat similar explanation which Professor A. G. Högbom has given of the Scolithus sandstone and the Pipe-rock (1915, Bull. Geol. Inst. Upsala, vol. xiii, pp. 45–60). And it is perhaps appropriate to mention here that in 1911 Mr. W. H. Twelvetrees, Government Geologist of Tasmania, sent to the Natural History Museum two specimens of "pipe-stem sandstone" of supposed annelid origin, but showing in thin section no structure other than grains of sand. "For the most part," said Mr. Twelvetrees, "the tubes are vertical to the bedding, but occasionally we

find them parallel to it. Sometimes they are as thick as a pencil. Sometimes they are trumpet-shaped. At one time we thought they were restricted to one geological horizon, but they evidently persist from our Cambrian or Cambro-Ordovician conglomerate, in which they occur sparsely, through the sandstone of doubtful Cambrian or Ordovician age to Silurian sandstone, in which they are also rare." The specimens are now in the Geological Department, registered A 1658.

In a reply to Mr. Twelvetrees, dated September 30, 1911, I compared the specimens with similar structures in the Cambrian sandstones of this country and of Sweden, in particular with a specimen obtained by me at Bergquara in Småland (Brit. Mus., Geol. Dept., A 1356), where such appearances are fairly common and have been referred to *Scolithus linearis*, Hall. Descriptions of these are given by N. O. Holst (1893, *Sveriges Geol. Undersökning*, ser. C, No. 130, p. 6) and Nathorst (1892, *Sveriges Geologi*, p. 117 and text-figures on p. 118). Though usually interpreted as the filled burrows of worms, Nathorst questions whether the structure has not rather arisen in a mechanical way. The cylinders are often packed so closely that I too was "inclined to regard the structure as due to some mechanical agency". Some American specimens in the British Museum, labelled *Scolithus*, do indicate the existence of burrows subsequently filled; but in the pipe-rock there is no evidence of this. I do not, however, understand how the tubes can ever be parallel to the bedding, as stated by Mr. Twelvetrees, if formed by ascending bubbles.

In another note (Proc. Roy. Soc. Victoria, n.s., vol. x, pp. 209–10) which Mr. Dunn published in May, 1898, he was tempted to ascribe numerous perforations in a decomposed steatitic rock near Coolgardie to worms, larvæ, or flies. He mentions, however, that the roots of eucalyptus trees follow these perforations to as great a depth as 150 feet from the surface. May it not be the case that the perforations were actually made by the eucalyptus roots? Such an action is by no means uncommon.

The weathering action of salt-solution through repeated wettings and dryings is one that I have attempted to apply in removing the matrix from the surface of fossils, or inducing differential weathering of a fossiliferous limestone with impure matrix. The mechanical principle of crystallization involved in the weathering is, as Mr. Dunn says, an intensification of the principle of repeated freezing and thawing in winter, and is more convenient for the palæontologist. The same effect may be attained by the use of the more readily crystallizing salt, sulphate of magnesia (Epsom salts). It is, however, a question whether there may not be in the case of sodium chloride some chemical action as well. Here reference may be made to the paper read by Professor R. C. Wallace at the Manchester Meeting of the British Association, 1915, "On the Corrosive Action of certain Brines in Manitoba." The third paragraph of the Abstract (published in the Association Report, p. 427, and in the Geol. Mag., Jan. 1916, p. 31) indicates a considerable chemical action, due to the fact that a persistent film of concentrated sodium

chloride acts in conjunction with the gases of the atmosphere. The evidence for all this is presumably given in Professor Wallace's complete paper, but I do not know whether that has yet been published. In the case of Mr. Dunn's pebbles, instead of a persistent film there is regular alternation of wet and dry, so that the chemical action, if any, must be considerably less than the mechanical; mere attrition appears to be excluded.

F. A. Bather.

OBITUARY.

FRANÇOIS CYRILLE GRAND'EURY.

Born March 9, 1839. Died July 22, 1917.

By the death of M. Grand'Eury palæobotany loses one of its most distinguished and energetic pioneers. As a mining engineer who spent his life in coal-fields, he had unrivalled opportunities for observing Carboniferous plants in situ, and he always made the most of every discovery which came under his notice. His special studies enabled him to correlate various roots, stems, foliage, and fruits which as isolated fossils had received separate names. He also made many important observations bearing on the origin of coal. His well-known memoir on the Carboniferous Flora of the Loire was published by the Paris Academy of Sciences so long ago as 1876. His great work on the Coal Basin of the Gard appeared in 1890. Numerous other publications culminated in his *Recherches géobotaniques*, which were in course of issue at the time of his death.

PROFESSOR EDWARD HULL,

M.A., LL.D., F.R.S., late Director Geological Survey of Ireland, and Professor of Geology Royal College of Science, Dublin.

Born May 21, 1829. Died October 18, 1917.

We regret to record the death of Professor Hull, at his residence, 14 Stanley Gardens, Notting Hill, W. 11, on October 18, aged 88.

A memorial service was held on Monday, October 22, at St. Peter's Church, Kensington Park Road, Notting Hill, and was attended by numerous representative scientific men.

A record of his life-work as a geologist will appear in December.

GEORGE C. CRICK,

Assoc. R.S.M., F.G.S., of the Geological Department, British Museum (Natural History).

Born October 9, 1856. Died October 18, 1917.

With sorrow we record the death at his residence, 20 Bernard Gardens, Wimbledon, in his 62nd year, of our former colleague, Mr. George C. Crick, well known as an authority on the fossil Cephalopoda, and author of numerous papers in this Magazine, the Proceedings of the Malacological Society, and the Quarterly Journal of the Geological Society.

A notice of Mr. Crick's scientific work will appear next month.

H. W.